

Vol. XXII, Part I

March, 1952

THE
INDIAN JOURNAL
OF
AGRICULTURAL SCIENCE

AGRICUL

10 FEB 1953

SERIAL
SEPARATE

As. 60 B

Issued under the authority

of

The Indian Council of Agricultural Research



सत्यमेव जयते

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 4 or 6s. 6d.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE GOVERNMENT OF INDIA PRESS, CALCUTTA, INDIA,
1952.

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The Publications Committee of Indian Council of Agricultural Research, India takes no responsibility for opinions expressed in Journal

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FURTHER INVESTIGATIONS ON THE PHOTOPERIODIC EFFECT IN JUTE

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(Received for publication on 26 December, 1950)

(With Plates I—III and 7 text-figures)

SINCE the discovery of the phenomenon of photoperiodism by Garner and Allard [1920], a large amount of work has been done with various plants in different parts of the world on the influence of daily light periods on the initiation of reproductive phase in plants and various attempts from different points of view are also being made to understand and analyse thoroughly the factors that play a part in bringing about the photoperiodic effect.

The influence of temperature on photoperiodic effect has received a wide interest and commencing the observation of Garner and Allard [1923], various investigations have shown that temperature may have a profound influence on photoperiodic effect, Borthwick, Parker and Scully [1943] on *Taraxacum Kok-saghyz*; Heath and Mathur [1944] on Onion; Heath [1943] on Onion; Naylor [1941] on Beet and Dill; Mann [1940] on *Xanthium*; Murneek [1940] on *Rudbeckia*; Snyder [1940] on Cocklebur and Biloxi Soyabean; Gilbert [1926] on *Xanthium*; Purvis [1934] on Rye; Mc. kinney and Sando [1935] on various plants; Roberts and Struckmeyer [1938 to 1939] on various plants—the effect of night temperature; Kopetz [1943] on pea; Steinberg and Garner [1936] on various plants. Sen and Pain [1948] have found that the photoperiodic effect is greatly influenced by season in *Sesamum*.

It has been observed by numerous investigators in a variety of plants that an initial treatment to a light period conducive to sexual reproduction will result in flower and fruit development though to various extents, irrespective of the length of the day to which the plants are subjected afterwards. This effect has been called 'Photoperiodic induction' or 'Photoperiodic after-effect' and seems to be true for both short and long day plants [Hamner, 1944]. Thus the effect of pre-treatment by light periods is brought into line with the parallel pre-treatment with temperature known as vernalization and recognition of this phenomenon has been of great value in detailed studies of photoperiodism in various plants and in analysis of the nature of photoperiodic reaction.

There is considerable evidence that the age of the plant determines to a great extent its sensitivity to length of day [Murneek, 1948; Hamner, 1944].

When the plant comes to flower either under natural or artificial photoperiod—their takes place a change in the vegetative growth [Murneek, 1948]. It is sometimes seen that the stem elongation is retarded at the initiation of flower by suitable photoperiodic treatments and this has been called photoperiodic inhibition [Murneek, 1948]. Stem elongation has been found to be inhibited by long day in Cucumber [Danielson, 1944] and by short day in some tobaccos [Dennison, 1945] but both of them are apparently day neutral plants.

Experiments on the photoperiodic effect in jute have shown that it may be called a 'short day' plant as the plant exposed to about 10 hours light period flowered in 32.6 days for *Corchorus capsularis* and 27.8 days in *C. olitorius* against 114 days in *C. capsularis* and 125 days in *C. olitorius* of plants exposed to the natural day light periods, when sown in April [Sen Gupta and Sen, 1944]. The same authors showed that in the plants exposed to long light periods of 16 hours, the flowering was delayed [Sen Gupta and Sen, 1948].

Plants sown in different months from April to July have been found to flower within a short period between the middle of August, and middle of September irrespective of sowing time. The flowering time thus falls at a time when the daily light period is decreasing [Sen Gupta and Sen, 1944, 1948].

In an investigation on the cause of early flowering in *C. olitorius* Sen Gupta and Sen [1947] found that this species flowers in 28 days when sown on 1 March, in 23 days when sown on 16 March and 60 per cent in 45 days and others in the normal period of 148 days, when sown on 31 March. In an attempt to find out the relative influence of the nitrogen supply to the soil, water supply to the soil, water sprayed in plants, they point out that the chief effective factor in the early flowering of *C. olitorius* is the short daily light period.

The present investigation was undertaken to obtain further information about the photoperiodic behaviour of jute plants viz., (a) the relative influence of other environmental factors chiefly temperature of different seasons, (b) effect of curtailing light periods in the morning and in the evening in the short period treatments, (c) the effect of light period treatment for different durations at the early stage to study induction effects, and (d) the effect of the age of the plant on the photoperiodic response and also to find out, (e) the influence of different photoperiodic treatments on the vegetative growth in relation to the onset of reproductive phase.

MATERIALS AND METHODS

Corchorus capsularis (D. 154) and *C. olitorius* (Chinsura green) the two recommended strains were used for the experiments. Pure strain seeds were obtained through the courtesy of Jute Agricultural Research Laboratory, Hooghly.

The different treatments of the different experiments and sowing dates are given in a tabular form below :

Experiment	Sown on	Treatments—light period in hours
1 Effect of other environmental factors of nature, chiefly temperature of different seasons	17.4.48 2.6.48 1.10.48	8 h., 10 h., 11 h., 12 h. and normal 8 h., 10 h., 11 h., 12 h., 14 h. and 16 h. and normal
2 Effect of curtailing light period in the morning just after sunrise and in the evening just before sunset in the short period treatments	17.4.48	8 h., 10 h. and normal
3 The effect of light period treatment for different durations at the early stage, to study induction effects.	17.4.48 2.6.48	8 h. for 14 days and 21 days 10 h. for 14 days and 21 days 10 h. for 7 days, 14 days and 30 days 14 h. for 7 days, 16 days, 30 days and 60 days
4 The effect of the age of the plants on the Photoperiodic effect	17.4.48	10 h. at the ages of 30, 60 and 90 days
5 The influence of the different photoperiodic treatments on the number of fruits formed	17.4.48 2.6.48 1.10.48	All treatments of all sowings

For the short light period treatments the plants were removed to a well ventilated darkroom after the completion of the respective short light periods and taken out in the open after dusk. For the additional hours of light exposure required to complete the long light period after sunset electric light was supplied from 200 C.P. bulb at a distance of 2.0 to 1.5 metres in a ventilated room and taken out in the open after the completion of the required long light periods.

There were 3 pots 13 in. × 13 in. each with 4 plants, i.e., 12 plants per treatment and control. As the plants grew the following readings were taken separately for each plant: The date of initiation of first visible flower bud taken as the *flowering date*, height in cm. at flowering, the date of initiation of first visible fruit taken as the *fruiting date* and the number of fruits per plant were counted. The data are expressed as the mean of 12 plants per treatment or less if any of them were dead or mutilated and entered in tabular form and represented in vertical graphs (Fig. 1).

EXPERIMENTAL RESULTS

The mean time of flowering and mean height at the time of flowering in centimeter and the fruiting time in days for the different dates of sowing and for the different continuous treatments from the beginning to fruiting are given in Table 1 for *C. capsularis* and Table II for *C. olitorius* and represented graphically in Fig. 2 for *C. capsularis* and Fig. 3 for *C. olitorius*. The treatments are however not the

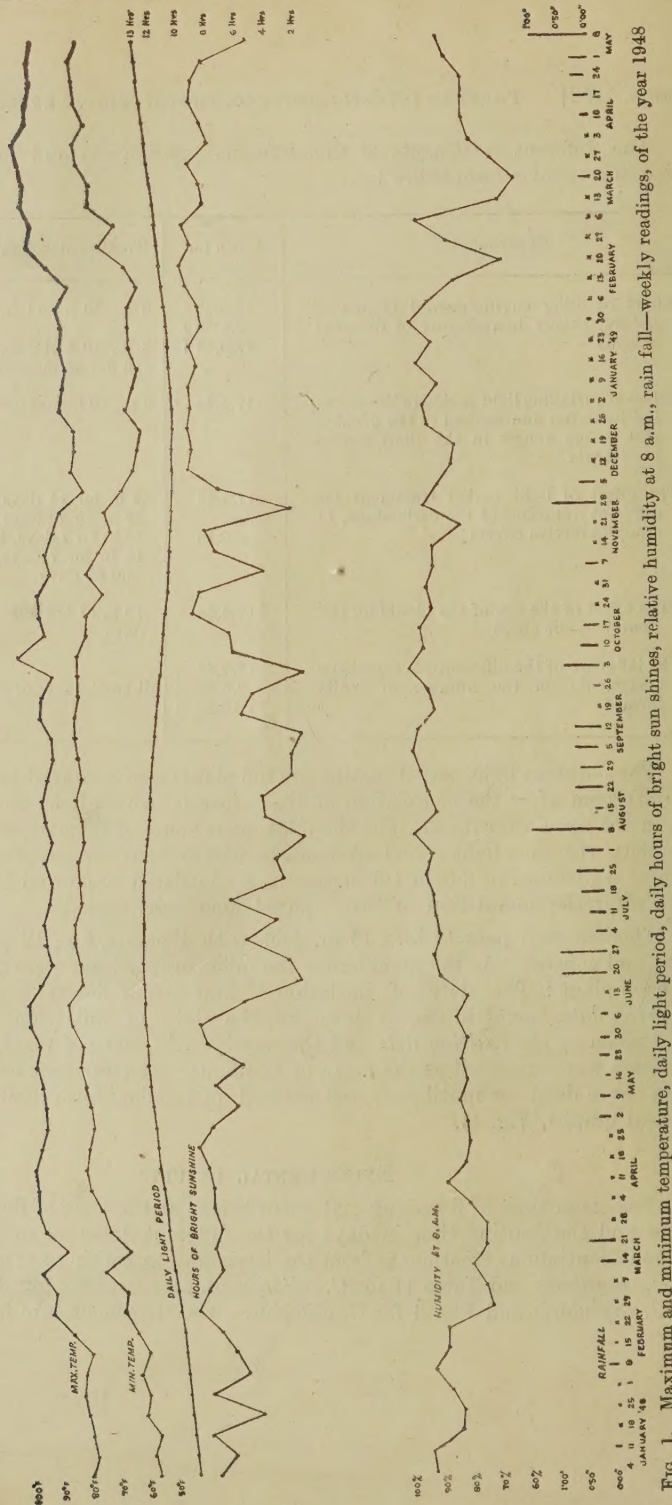


FIG. 1. Maximum and minimum temperature, daily light period, daily hours of bright sun shines, relative humidity at 8 a.m., rain fall—weekly readings, of the year 1948

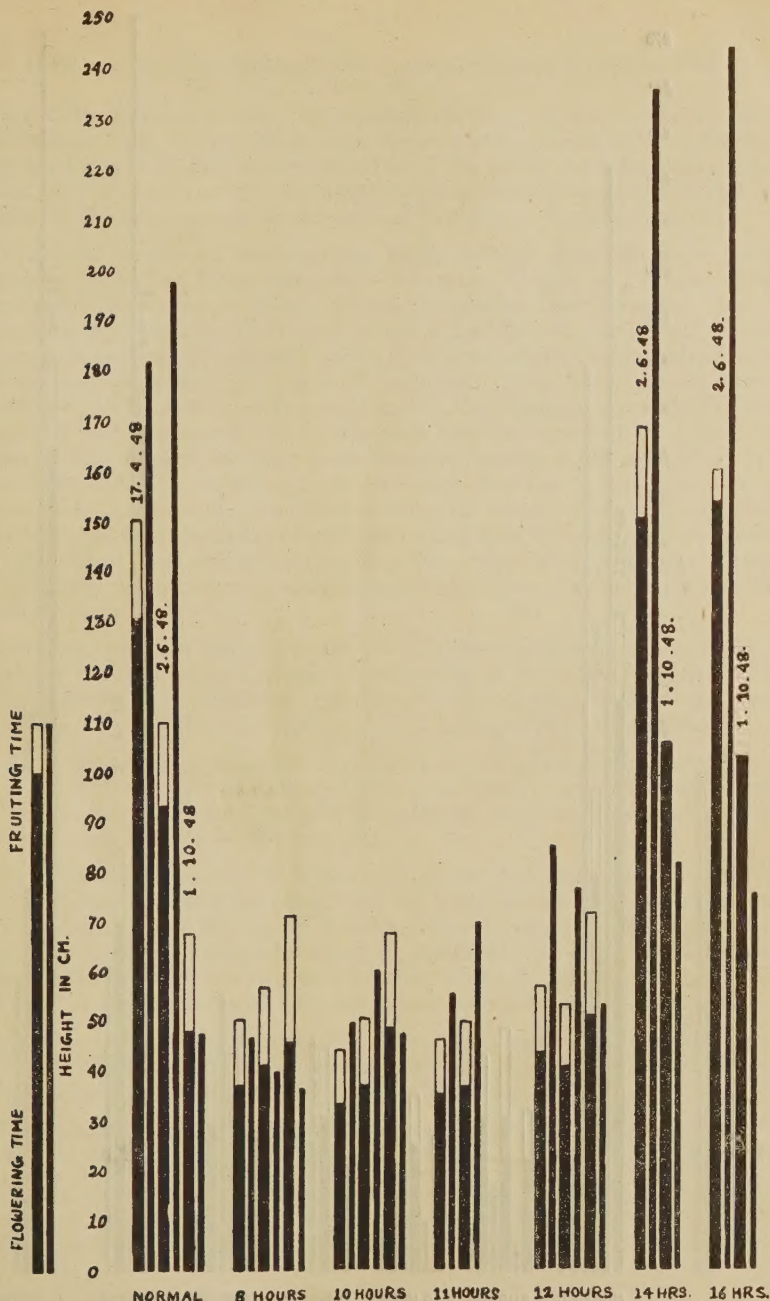


FIG. 2. Effect of short and long light periods on the flowering, fruiting and height at the stage of flowering in *C. capsularis* in three sowings of 17.4.48, 2.6.48 and 1.10.48. The ordinate represents both time in days and height in centimeters

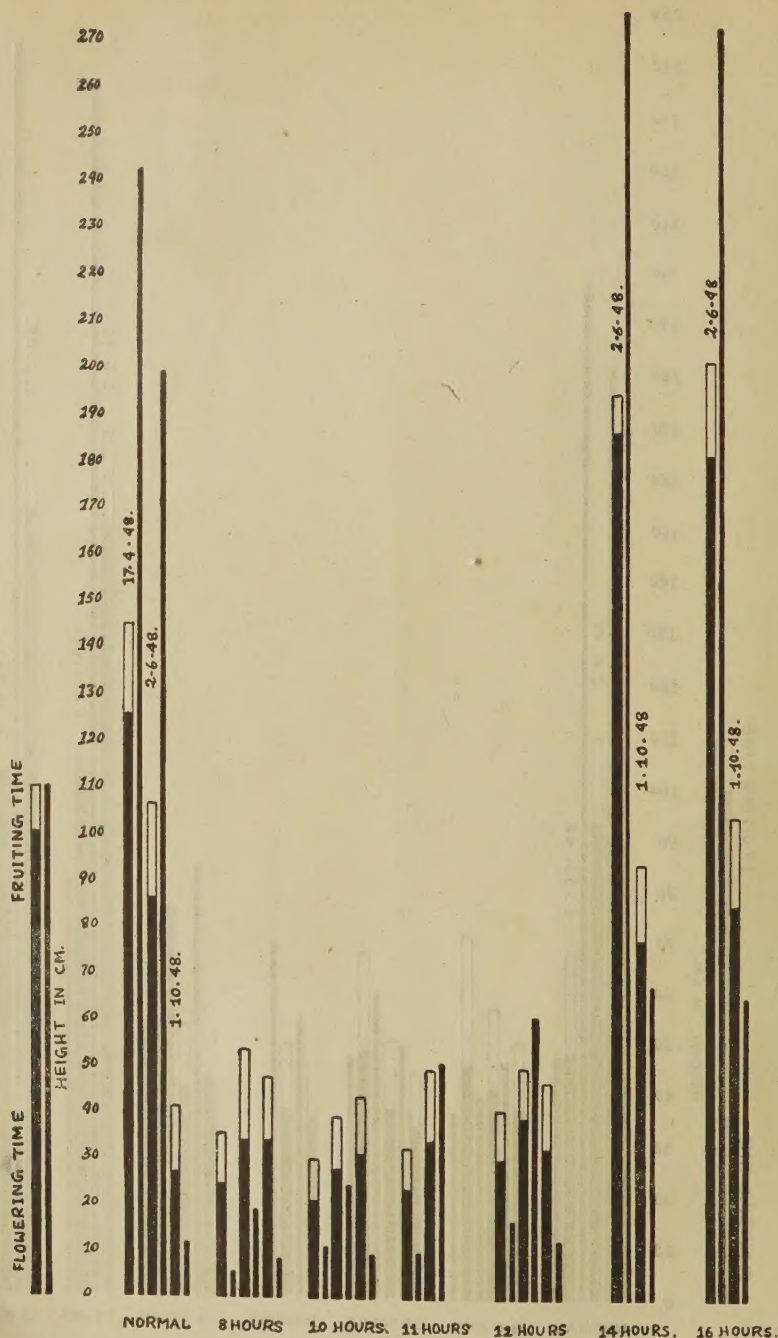


FIG. 3. Effect of short and long light periods on the flowering, fruiting and height at the stage of flowering in *C. olitorius* in three sowings of 17-4-48, 2-6-48 and 1-10-48. The ordinate represents both time in days and height in centimeter

same for all the times of sowing. In recording the flowering and fruiting of plants of the 14 hours and 16 hours treatments it was found that a few plants flowered usually after a spell of dark cloudy days, but all the plants did not produce flower or fruits, and in such cases the percentages of plants that flowered and fruited are indicated in the same column as the time of flowering or fruiting in days.

It may be mentioned here that the plants specially those which are photo-periodically induced to flower early show interesting changes at the onset of the flower buds in the development of a branch or branches near the apex. Just at the initiation of flower buds the branch at the axil of the last mature leaf towards the apex grow out very prominently and in *C. olitorius* after a few days this branch becomes equally prominent as the growing main axis. From this prominent branch near the apex and also the growing main axis further branches arise—which however are not very prominent. In *C. capsularis* also the branch at the axil of the last mature leaf towards the apex grows out prominently at the onset of the first visible flower bud. But in this species the branch does not become as prominent in the case of *C. olitorius* and moreover as the main axis grows on in *C. capsularis* further branches from the axils of leaves are produced on the main stem above and below the original prominent branch so that after a time the apical portion of these flowering plants give a bushy appearance due to the growth of a number of branches on the main stem.

The flower buds are produced in the younger portions of the main stem as well on the branches in a position opposite to the point of insertion of the leaf. The number of flower buds and flowers produced from each point at the node varies between one, two and three and the number of fruits between one and two.

As the vegetative growth after flowering is more vigorous in the plants which are induced to flower early as compared with those which flower late in the normal time the branches which are formed at flowering are much more prominent in the plants which are induced to flower early.

The plants under normal daily light period had a straight stem in both the species with small branches appearing from the lower internodes as the plant grew in *C. capsularis*. There was apical branching after flowering as in the short day treated plants but the branches were not so prominent. In every case of flowering irrespective of earliness or lateness the onset of the reproductive phase is associated with the development of branches mentioned above in both the species.

It is seen that the plants exposed to short light periods of 8 hours, 10 hours, 11 hours and 12 hours flowered much earlier than those exposed to the normal daily light period, and thus *C. capsularis* is a short day plant.

The plant of the normal light periods flowered latest in 17.4.48 sowing in 130.9 days, next in 2.6.48 sowing in 93.1 days and earliest in 1.10.48 sowing in 48.2 days.

But the plants exposed to short light periods of 8, 10 and 12 hours flowered earliest in 17.4.48 sowing, next in 2.6.48 sowing and latest in 1.10.48 sowing, the flowering thus being delayed with the lateness of sowing. It will be noted that

TABLE I

C. capsularis

Time of flowering, height in cm. at flowering time and the fruiting time in days for the different sowings and the different continuous light period treatments

	17.4.43				2.6.43				1.10.43			
	Height at flowering		Flowering time in days		Height at flowering		Flowering time in days		Height at flowering		Flowering time in days	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
—												
8 hours	46.96	± 5.75	37.17	± 3.44	40.29	± 1.39	41.25	± 3.71	36.6	± 1.68	48.75	± 3.81
10 "	49.78	± 2.19	33.59	± 4.84	60.32	± 2.03	37.25	± 1.21	47.35	± 1.29	48.80	± 6.75
11 "	55.57	± 1.99	35.75	± 3.51	70.2	± 1.59	37.08	± 4.34	..	..	..	..
12 "	85.20	± 3.29	43.75	± 1.47	76.84	± 2.09	40.84	± 4.89	53.32	± 1.47	51.35	± 8.26
14 "	..	..	..	..	236.06	± 4.42	150.7 (83.3 percent)	± 2.02	81.52	± 4.03	106.0* (72.7 percent)	± 6.54
16 "	..	..	..	..	243.92	± 5.77	154.3 (75.0 percent)	± 5.24	75.87	± 4.17	103.3* (83.3 percent)	± 3.47
Normal	132.23	± 4.75	130.92	± 7.63	197.97	± 4.51	93.08	± 3.91	47.74	± 1.25	48.17	± 9.03
Daily light period	12h.35m.—13h.31m.—12h. 27m.				13h.25m.—13h.31m.—12h. 27m.				11h.51m.—10h.45m.			

* Flowering took place after treatment stopped.

** Fruits formed but did not develop.

the 8-hour and 10-hour treated plants of the 1.10.48 sowing flowered about the same time as normal ones but the 12-hour treated plants flowered slightly later than the normal but it should be remembered that the normal light period of this sowing gradually decreased from 11 hours 55 minutes at the time of sowing to 11 hours 0 minute at the time of flowering and the daily light period was thus distinctly lower than 12 hours. In the 17.4.48 sowing the 8-hour treated plants flowered a little later than the 10-hour treated plants, but between 10, 11 and 12-hour treatments the flowering was gradually delayed with the increase in light period. In the 2.6.48 sowing on the other hand among the short light period treatments 8-hour treated plants are seen to flower latest, slightly later than 12-hour treatment although the difference is not significant and the 10-hour and 11-hour treated plants flowered practically at the same time, earlier than 8-hour and 12 hour treatments.

The plants exposed to long light periods of 14 hours and 16 hours flowered much later than the normal in both the sowings, which is to be expected as this is a short day plant.

It will be noted that in both the sowings flowering did not take place in all the plants of 14 and 16-hours treatments and the percentages of plants that flowered are indicated. The flowering of plants of these treatments of 2.6.48 sowing took place after a spell of three to five days of dark cloudy days when the hours of bright sunshine came down to 2.91-hours, and the 16-hour treated plants flowered later than the 14-hour treated ones. The plants of 1.10 sowing treated for 14-hour and 16-hour gave a diseased appearance and they were transferred to the normal daily light period (of about 10 hours 46 minutes) after 92 days from sowing. Flowering took place after this removal and again the flowering was not noticed in all of them after the periods mentioned in the Table I, the percentages of plants that flowered are indicated.

There was no production of fruits in the long light treatments of 1-10 sowing and in fact the plants died soon after flowering evidently due to the low temperature of January having an adverse effect on growth. No fruits were formed in any of the plants that flowered under these treatments of 14 hours and 16 hours of 2.6.48 sowing and those that were initiated did not develop into mature fruits and were shed soon after their initiation.

If now the heights reached by plants of different treatments at flowering are considered it is found firstly that the normal of 2.6.48 sowing grow much taller (197.9 cm. in 93.1 days) than that of 17.4.48 sowing (182.2 cm. in 130.9 days) and the rate of growth was thus distinctly higher in the 2.6 sowing. The same is seen in the heights of different treatments of the two sowings. The rate of growth of plants of 1.10.48 sowing is even lower than that of 17.4.48 sowing. In general the heights at flowering increased with increase of daily light period, but in 1.10.48 sowing slightly higher growth in height is seen in 14-hour treatment than in 16-hour treated plants.

It is seen that the number of days required for the plants to produce fruits after flowering increased with lateness of flowering; also in the short day treated

plants this time increased with lateness of sowing and in the plants of 1.10.48 sowing 8-hour treated plants required the greatest number of days.

The flowering and fruiting time in days and the heights at the time of flowering in *C. olitorius* for the different sowings and the different treatments are given in Table II.

This species also behaved similarly as *C. capsularis* and is also clearly a short day plant. The variation due to the different light period treatments with reference to the different times of sowing are similar in nature in the two species.

It will however be noted that the flowering time is much more clearly shortened in the short day treatments in this species than in *C. capsularis*. In the 10-hours treatment the plant flowered in 21 days with a height of 11 cm. against 125.7 days and 142.6 cm. height for the normal, showing an earliness of 105 days.

In this species also the long day treated plants of the 1.10.48 sowing became sickly but not to the extent of *C. capsularis* and the plants could not be exposed to continued treatment till flowering. It will be noted that the plants of 1.10 sowing flowered much earlier in the 14-hour and 16-hour treatment than the similarly treated plants of 2.6 sowing. The height reached was also low in the 1.10 sowing and these were evidently due to the lower temperature of nature to which these plants were exposed.

In 2.6.48 sowing the *C. olitorius* plants under 14-hour and 16-hour treated plants flowered later than the *C. capsularis*, and the effect of long photoperiod was more marked in these plants.

The flowering time, fruiting times and heights at flowering of plants treated with 8-hour and 10-hour, light periods, but in one set the daily light period was shortened by curtailing the light period by suitable periods in the evening before dusk and in the other case the light period was curtailed by darkening for suitable periods in the morning following the sunrise are reported by Sen Gupta and Sen [1950] (i) and represented graphically in Fig. 4 or both the species.

Effect of photoperiodic treatments for different periods at the early stages

Induction effect. It will be noted that in 17.4.48 sowing there is no long light period treatment as the electrical arrangements of the newly constructed ventilated rooms was not completed before that time, and in the 2.6.48 sowing greater stress has been laid on the long light period treatments.

The mean time of flowering and mean height at the time of flowering in cm. and the fruiting time in days for the treatments of different light periods and for different durations are given in Table III for *C. capsularis* and Table IV for *C. olitorius*, and represented graphically in Fig. 5 for *C. capsularis* and in Fig. 6 for *C. olitorius*. The respective light treatments were continued upto flowering and fruiting and the readings of the normal plants of the respective sowings are given in the tables for comparison. (The results have been discussed by Sen Gupta and Sen (1950) ii.)

TABLE II

C. chlorius

Time of flowering, height in cm. at flowering time and fruiting time in days for the different sowings under different continuous light period treatments

	17.4.43				2.6.43				1.10.43			
	Height at flowering		Flowering time in days		Height at flowering		Flowering time in days		Height at flowering		Flowering time in days	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
8 hours	5.89	±.251	24.59	±.149	19.37	±1.85	34.17	± 1.29	8.53	±.491	34.0	±.062
0 "	11.02	±.391	21.0	±.213	24.49	±.279	27.92	± 1.05	9.49	±.846	31.09	±.048
11 "	9.95	±.392	23.4	±.259	50.5	±3.38	34.0	±.843	..	..	..	..
12 "	17.05	±.2.41	30.68	±1.27	60.1	±.207	39.08	±.609	12.72	±.691	32.28	±.776
14 "	..	..	..	..	275.49	±6.74	185.09 (91.6 percent)	±.4.29	66.04	±3.49	76.7	±.284
13 "	..	..	..	..	271.5	..	180.0 (83.8 percent)	(1 out of 12 plants)	64.44	±4.28	84.0 (94.6 percent)	±1.11
Normal	242.56	+7.46	125.7	±.891	193.85	7.29	86.70	±.2.42	11.93	±.551	27.2	±.742
Daily light period	12h. 35m.—13h. 2	31—m.12h.7m.	13h. 25m.—13h. 31m.—12h. 27m.	11h. 51m.—10h. 45m								

** Fruits formed but did not develop

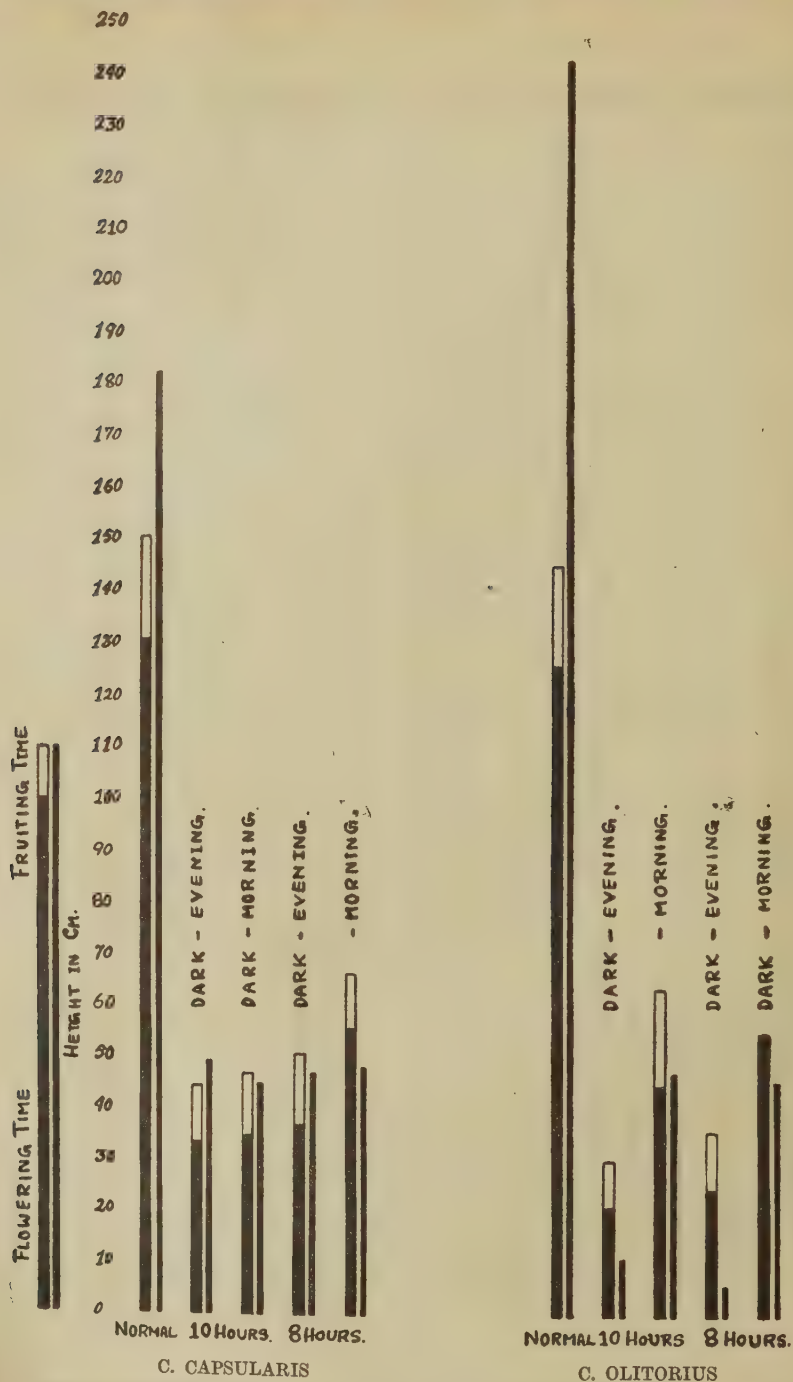


FIG. 4. Effect of darkening in the morning in 8 hours and 10 hours photoperiodic treatments on the flowering, fruiting and height at the stage of flowering in *C. capsularis* and *C. olitorius*—sown on 17-4-48. The ordinate represents both time in days and height in cm.

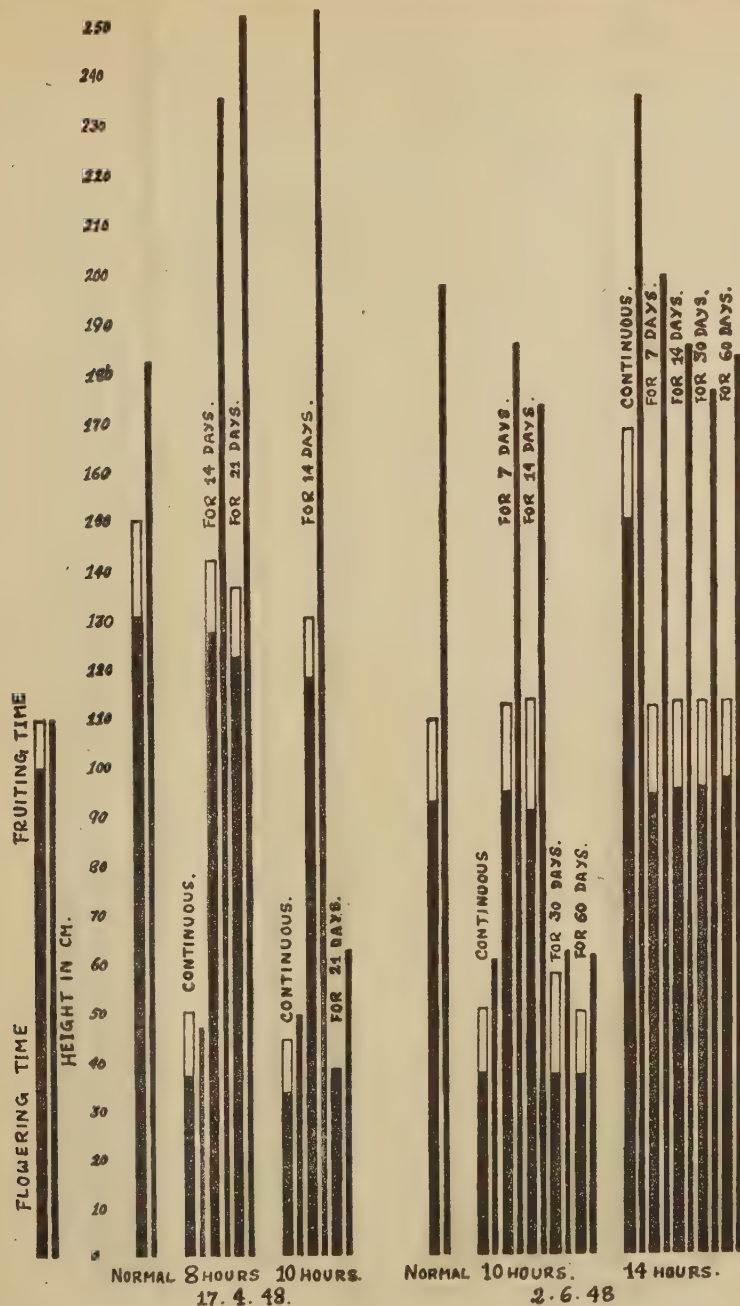


FIG. 5. Effect of different short and long photoperiods of different durations at the early stage on the flowering, fruiting and height at the stage of flowering in *C. capsularis*—sown on 17.4.48 and 2.6.48. The ordinate represents both time in days and height in centimeters

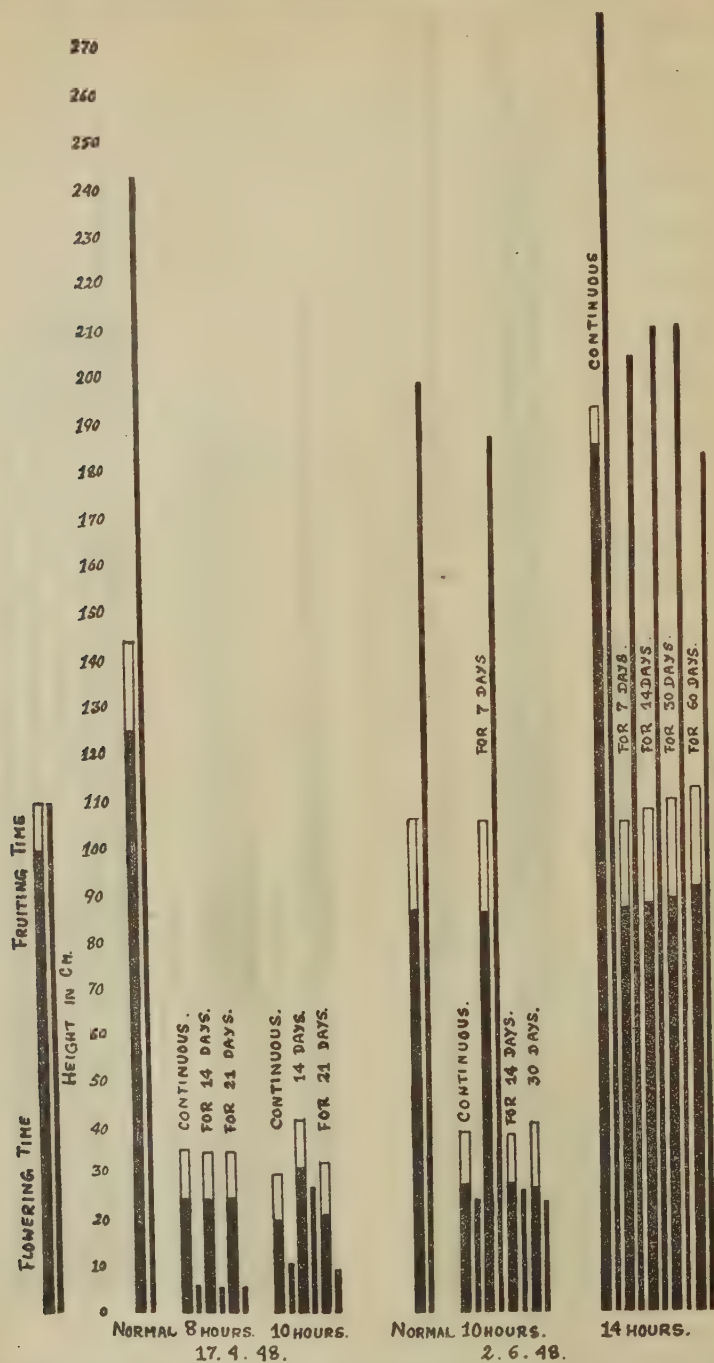


FIG. 6. Effect of different short and long photoperiods of different durations at the early stage on the flowering, fruiting and height at the stage of flowering in *C. olitorius*—sown on 17-4-48 and 2-6-48. The ordinate represents both time in days and height in centimeters²

TABLE III

C. capsularis

Time of flowering, height in cm. at flowering time and fruiting time in days of the plant under different long and short photoperiods at the early stages

Treatment	Period of treatment	Height at the time of flowering in cm.				Flowering time in days after sowing				Fruiting time in days	
		17-4-48		2-6-48		17-4-48		2-6-48		17-4-48	2-6-48
		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Days	Days
8 hours	treatment for 14 days	236-12	±7-16	..	..	127-50	±7-12	..	..	142-6	..
8 do.	" " 21 "	252-62	±6-16	..	..	122-92	±2-1	..	..	137-1	..
8 do.	continuous	46-96	±5-75	..	..	37-17	±3-44	..	..	50-4	..
10 do.	treatment for 7 days	..	..	186-29	±5-51	..	..	95-0	±1-02	..	..
10 do.	" " 14 "	253-42	±9-37	173-78	±4-66	118-50	±2-18	91-08	±1-75	130-9	..
10 do.	" " 21 "	62-45	±1-17	..	..	*88-56	±2-22	..	..	No*	114-0
10 do.	" " 30 "	..	..	61-83	±9-11	..	..	37-08	±1-93	..	57-9
10 do.	continuous	49-78	±2-19	60-32	±2-03	83-59	±4-84	37-27	±1-21	44-6	50-7
14 do.	treatment for 7 days	..	..	200-00	±5-41	..	..	94-75	±2-01	..	112-5
14 do.	" " 14 "	..	..	135-82	±6-85	..	..	95-4	±4-82	..	113-7
14 do.	" " 30 "	..	..	176-59	±4-39	..	..	96-08	±9-72	..	113-8
14 do.	" " 60 "	..	..	183-4	±3-81	..	..	87-5	±3-79	..	113-5
14 do.	continuous	..	..	238-06	±4-42	..	..	150-7	±2-02	..	169-2
Normal (Control)		182-23	±4-75	197-97	±4-51	130-92	±7-63	93-08	±3-19	150-6	110-2

*These plants produced early flowers once, but they were abortive and after further vegetative growth that produced flowers a second time about the same time as normal

TABLE IV

C. olitorius

Time of flowering, height on cm. at the time of flowering and fruiting time in days of the plants under different long and short photoperiods at the early stages of different duration

Treatment	Period of treatment	Height at the time of flowering in cm.				Flowering time in days after sowing				Fruiting time in days	
		17-4-48		2-6-48		17-4-48		2-6-48		17-4-48	2-6-48
		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	Mean
8 hours	treatment for 14 days	5.79	±.882	—	—	25.0	±.389	—	—	35.3	—
8 do.	" 14 "	5.74	±.264	—	—	24.70	±.355	—	—	35.1	—
8 do.	continuous	5.89	±.251	—	—	24.59	±.149	—	—	35.7	—
10 do.	Treatment for 7 days	—	—	186.69	±.607	—	—	86.17	±.118	—	105.3
10 do.	" 14 "	27.61	±19.08	26.69	±1.41	31.84	±.721	28.0	±.564	41.8	38.7
10 do.	" 21 "	9.82	±.435	—	—	22.08	±.259	—	—	32.3	—
10 do.	" 30 "	—	—	23.09	±.229	—	—	27.08	±.701	—	40.9
10 do.	Continuous	11.02	±.391	24.49	±.279	21.0	±.213	27.92	±.105	30.2	39.2
14 do.	Treatment for 7 days	—	—	203.84	±.652	—	—	86.84	±.106	—	105.0
14 do.	" 14 "	—	—	209.44	±.627	—	—	87.70	±.126	—	107.7
14 do.	" 30 "	—	—	209.95	±.447	—	—	88.70	±.879	—	109.8
14 do.	" 60 "	—	—	182.64	±.761	—	—	91.25	±.843	—	112.4
14 do.	Continuous	—	—	275.49	±.674	—	—	135.09	±.429	—	133.0 (35.3) per cent
Normal (Control)		242.56	±.746	198.85	±.729	125.7	±.891	86.70	±.242	144.7	106.2

It will be seen that in *C. capsularis* 8 hours light treatment for 14 days and 21 days and also 10 hours treatment for 14 days produce some earliness of flowering whereas the earliness of flowering is much more pronounced with continuous 8 hours treatment and the flowering takes place earliest in continuous 10 hours treatment. Fourteen days treatments in 10 hours causes more distinct earliness in flowering than 14 days treatment in 8 hours. Plants when treated for 21 days in 10 hours light period the earliness is only 5 days less than the continuous 10 hours treatment in the 17-4-48 sowing. Although these plants under 10 hours treatment for 21 days produced early flowers, the flowers were abortive and no fruits were formed; after a further period of vegetative growth they produced flowers a second time about the same time as normal ones.

It is very remarkable that in 17-4-48 sowing 8 hours and 10 hours treatment for 14 days and 8 hours treatment for 21 days causes a great acceleration of vegetative growth the height reached by these plants being much greater than even the normal ones.

In the 2-6-48 sowing 10 hours treatment for 14 days cause a slight earliness of 2 days in flowering than normal but treated for 30 days the plants flowered practically at the same time as the 10 hours continuous treatment and the slight differences among them are not significant. It is remarkable that 10 hours treatment for 7 days produced flowers a little later than normal and the lateness though of 1.92 days only is statistically significant.

In the 14 hours light treatment even 7 days treatment caused a lateness of flowering and the lateness increased with the duration of treatment 7 days, 14 days, 30 days and 60 days, but the differences in flowering time between 7 days and 14 days, 14 days and 30 days, and 30 days and 60 days treatment are not statistically significant. The continuous 14 hours treatment however showed a lateness of flowering of about 57 days and were 37 cm. taller than the normal plants.

It will be seen that the species *C. olitorius* is much more sensitive to the light period treatments and also show reactions after shorter periods of treatments than *C. capsularis*. In the 8 hours treatment of the 17-4-48 sowing it is seen that there is no significant difference between the continuous, 14 days and 21 days treatments. The shortest flowering time of 21 days is seen in 10 hours treatment, and here also there is no significant difference between continuous and 21 days treatment, but 14 days treatment flower distinctly later. The height at which flowering takes place in these cases is very low as the flowering time is also very short. In the 14 hours treatment of 2-6-48 sowing the continuous treatment shows a great lateness of flowering (99 days), a much greater height (76 cm.) compared with the normal, but in 7 days, 14 days, and 30 days treatment flowering takes place practically at the same time as the normal, the differences being insignificant, but 60 days treatment causes a significant lateness in flowering.

In the 2-6-48 sowing 10 hours treatment for 14 days shows a very clear earliness but 10 hours 7 days treatment showed no difference from the control.

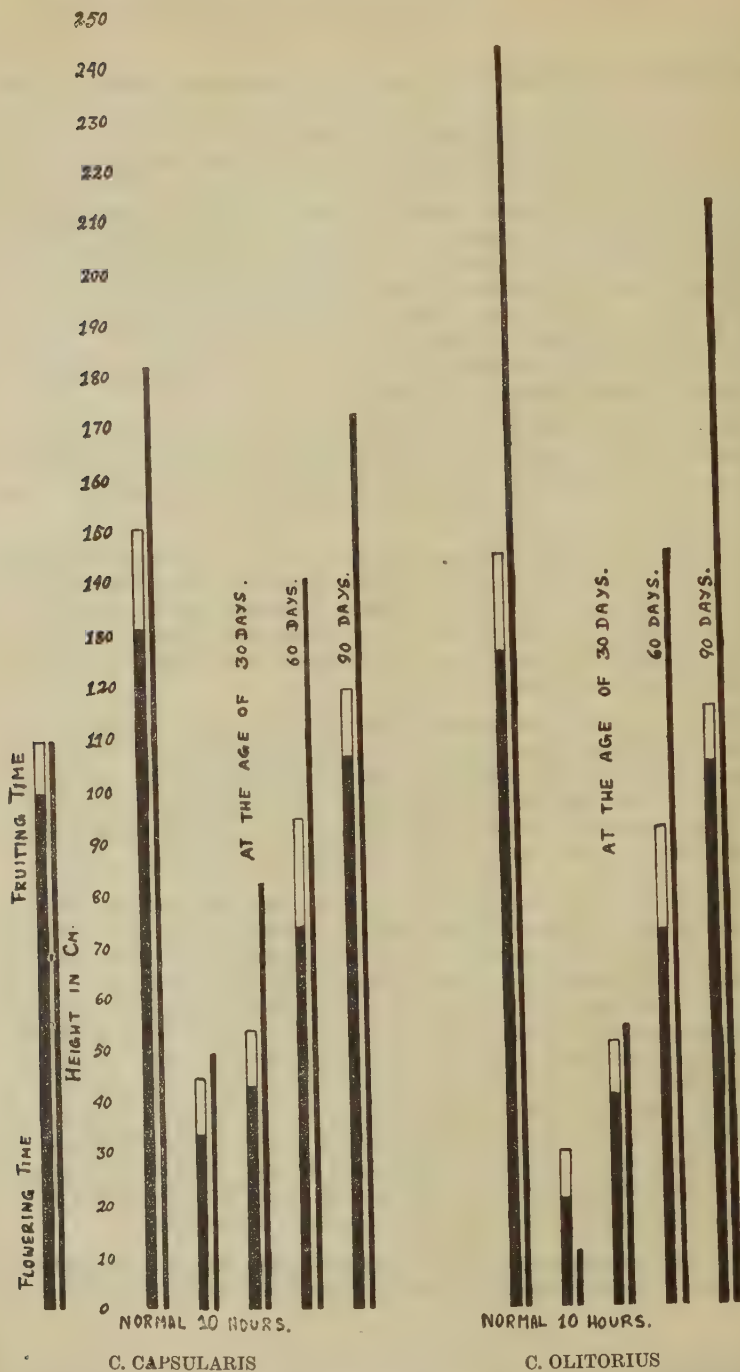


FIG. 7. Effect of 10 hours photoperiod commenced at different ages of 30, 60 and 90 days on the flowering fruiting and height at the stage of flowering in *C. capsularis* and in *C. olitorius*—sown on 17-4-48. The ordinate represents both time in days and height in centimeters

Effect of photoperiodic treatments at different ages

The effect of the short day treatment of 10 hours at different ages of the plants of the 17-4-48 sowing on the flowering and fruiting time and the mean height at flowering are given in Table V for *C. capsularis* and Table VI for *C. olitorius*, and represented graphically in Fig. 7 for both the species.

TABLE V

C. capsularis

Time of flowering, height in cm. at the time of flowering and fruiting time in days of plants treated under short photoperiod at different ages

	Height in cm.		Flowering time in days after sowing		Flowering time in days after commencement of treatment	Fruiting time in days
	Mean	S.E.	Mean	S.E.		
10 hours continuous	49.78	±2.19	33.59	±.484	28.59	44.6
10 hours at the age of 30 days	81.94	±2.19	43.09	±.499	13.09	53.7
10 hours at the age of 60 days	140.37	±3.98	73.75	±.250	13.75	94.8
10 hours at the age of 90 days	172.2	±6.62	106.25	±.509	16.25	119.2
Normal	182.23	±4.75	130.92	±.763	—	150.6

TABLE VI

C. olitorius

Time of flowering, height in cm. at the flowering time and fruiting time in days of plant treated under short photoperiod at different ages

	Height in cm.		Flowering time in days after sowing		Flowering time in days after commencement of treatment	Fruiting time in days
	Mean	S.E.	Mean	S.E.		
10 hours continuous	11.02	.391	21.0	.213	16.0	30.2
10 hours at the age of 30 days	53.65	1.81	40.7	.188	10.7	50.6
10 hours at the age of 60 days	144.70	4.37	72.0	.536	12.0	91.7
10 hours at the age of 90 days	211.92	6.37	103.42	.688	13.42	114.7
Normal	242.56	7.46	125.7	.891	—	144.7

It is seen that when the vegetative growth has proceeded under normal condition for 30 days and more, the number of days of 10 hours treatment required for initiation of flowering is much less than when the treatment is commenced from the beginning of growth, that is 5 days after sowing. This is true for both the species.

Number of fruits formed

Number of fruits formed due to the different photoperiodic treatments in the two species is given in Table VII.

TABLE VII

Mean number of fruits formed due to different treatments in the three sowings of the two species

Treatments	Mean number of fruits formed					
	<i>C. capsularis</i>			<i>C. olitorius</i>		
	17-4-48	2-6-48	1-10-48	17-4-48	2-6-48	1-10-48
Normal light period	88.7	107.1	6.8	36.8	38.2	4.9
8 hours " "	11.3	59.7	7.7	14.3	32.8	4.3
10 " " "	23.8	41.2	12.1	20.2	35.0	5.5
11 " " "	20.9	35.7	—	20.6	31.1	—
12 " " "	29.1	40.9	3.3	29.2	28.3	3.8
14 " " "	—	0	0	—	0	0
16 " " "	—	0	0	—	0	0
8 " dark in the morning	14.8	—	—	5.0	—	—
10 " " " "	50.1	—	—	18.8	—	—
10 " after 30 days	14.6	—	—	27.9	—	—
10 " " 60 "	19.7	—	—	23.3	—	—
10 " " 90 "	54.3	—	—	20.5	—	—
8 " for 14 "	128.8	—	—	18.4	—	—
8 " " 21 "	159.1	—	—	14.6	—	—
10 " " 7 "	—	45.0	—	—	36.3	—
10 " " 14 "	113.1	35.1	—	20.6	35.2	—
10 " " 21 "	0*	—	—	14.7	—	—
10 " " 30 "	—	75.7	—	—	25.4	—
14 " " 7 "	—	58.1	—	—	46.2	—
14 " " 14 "	—	41.1	—	—	34.5	—
14 " " 30 "	—	42.0	—	—	42.0	—
14 " " 60 "	—	43.4	—	—	29.2	—

*Fruits formed were immature and shed early

In both the species the number of fruits formed were greater in all the treatments of 2-6-48 sowing compared with the same treatments of the other two sowings; the plants of different treatments of 1-10-48 sowing produced very few fruits [Sen Gupta and Sen 1950 (iii)]. Within the different treatments of each sowing the differences in the number of fruits are not as distinct in *C. olitorius* as in *C. capsularis*. No fruits were formed in the continuous long light period treatments of 14 hours and 16 hours in both the species. In *C. capsularis*, in the continuous short day treatments the number of fruits formed were much lower than in the normal of 17-4 sowing. The largest number of fruits formed were in 8 hours treatment for 14 days, 10 hours treatment for 14 days, and 8 hours treatment for 21 days, where the number of fruits formed are very large. These plants, it may be mentioned, were also characterized by a great enhancement of the vegetative growth.

The mean time of flowering and mean height at the time of flowering with their standard errors and levels of significance are given in order of magnitude for the different treatments of the three sowings separately in Tables VIII, IX and X for *C. capsularis* and in Tables XI, XII, XIII for *C. olitorius*.

TABLE VIII

C. capsularis (Sown on 17-4-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
10 hours induction for 14 days	253.42	± 9.37	Control in normal light	130.92	± .763
8 " " " 21 "	252.62	± 6.16	8 hours induction for 14 days	127.50	± .712
8 " " " 14 "	236.12	± 7.16	8 hours " " 21 "	122.92	± 2.11
Control in normal light	182.23	± 4.75	10 hours " " 14 "	118.50	± 2.18
10 hours at the age of 3 months	172.2	± 6.62	10 hours at the age of 3 months	106.25	± .509
10 hours " " 2 "	140.37	± 3.98	10 hours " " 2 "	73.75	± .250
12 hours light period	85.29	± 3.29	8 hours reduction from morning.	55.59	± 1.67
10 hours at the age of 1 month	81.94	± 2.98	12 hours light period	43.75	± 1.47
10 hours induction for 21 days	62.45	± 1.17	10 hours at the age of 1 month	43.09	± .499
11 hours light period	55.57	± 1.99	10 hours induction for 21 days	38.56	± .242
10 hours light period	49.78	± 2.19	8 hours light period	37.17	± .344
8 hours reduction from morning	47.87	± 2.04	11 hours light period	35.75	± .351
8 hours light period	46.96	± 5.75	10 hours light period	35.17	± .344
10 hours reduction from morning	46.16	± 1.53	10 hours reduction from morning.	35.09	± .336
10 hours light period	35.44	± 1.32	10 hours light period	33.59	± .484

Line across indicates insignificant

N.B.— $\sqrt{2}$ s. t. 5 per cent = 3.726N.B.— $\sqrt{2}$ s. t. 5 per cent = .837

TABLE IX

C. capsularis (Sown on 2-6-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
16 hours light period	243.62	±5.77	16 hours light period	154.3	±5.24
14 hours light period	236.06	±4.42	14 hours light period	150.7	±2.02
14 hours induction for 7 days	200.00	±5.41	14 hours induction for 60 days	97.5	±.379
Normal daily light period	197.97	±4.51	14 hours induction for 30 days	96.08	±.972
10 hours induction for 7 days	186.29	±5.51	14 hours induction for 14 days	95.40	±.482
14 hours induction for 14 days	185.82		10 hours induction for 7 days	95.0	±1.02
14 hours induction for 60 days	183.4		14 hours induction for 7 days	94.75	±2.01
14 hours induction for 30 days	176.59	±4.39	Normal daily light period	93.08	±3.19
10 hours induction for 14 days	173.78		10 hours induction for 14 days	91.08	±1.75
12 hours light period	76.84	±2.09	8 hours light period	41.25	±.371
11 hours light period	70.2	±1.59	12 hours light period	40.84	±.489
10 hours induction for 30 days	61.83	±.911	10 hours induction for 60 days	37.42	±1.42
10 hours induction for 60 days	61.32	±2.61	10 hours light period	37.25	±1.21
10 hours light period	60.32	±2.03	11 hours light period	37.08	±.434
8 hours light period	40.29	±1.39	10 hours induction for 30 days	37.08	±.193

Line across indicates insignificant

N.B.— $\sqrt{2}$, s. t. 5 per cent=3.34N.B.— $\sqrt{2}$, s. t. 5 per cent=1.53

TABLE X
C. capsularis (Sown on 1-10-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
14 hours light period	81.52	± 4.03	14 hours light period	106.0	± .654
16 hours " "	75.87	± 4.17	16 hours " "	103.3	± .347
12 hours " "	53.32	± 1.47	12 hours " "	51.25	± .826
Normal daily light period	47.74	± 1.25	10 hours " "	48.80	± .675
10 hours light period	47.35	± 1.29	8 hours " "	48.75	± .881
8 hours " "	36.60	± 1.68	Normal daily light period	48.17	± .908

N.B.— $\sqrt{2}$ s. t. 5 per cent = 2.14

N.B.— $\sqrt{2}$ s. t. 5 per cent = .603

Line across indicates insignificant

TABLE XI
C. olitorius (Sown on 17-4-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
Normal daily light period	242.56	± 7.46	Normal daily light period	125.7	± .891
10 hours at the age of 3 months	211.92	± 6.37	10 hours at the age of 3 months	103.42	± .668
10 hours at the age of 2 months	144.70	± 4.37	10 hours at the age of 2 months	72.0	± .536
10 hours at the age of 1 month	53.65	± 1.81	8 hours reduction from morning	54.62	± 4.23
10 hours reduction from morning	47.05	± 10.37	10 hours reduction from morning	44.5	± 4.83
8 hours reduction from morning	45.30	± 6.21	10 hours at the age of 1 month	40.7	± .188
10 hours induction for 14 days	27.61	± 19.08	10 hours induction for 14 days	31.84	± 7.21
12 hours light period	17.05	± 2.41	12 hours light period	30.08	± 1.27
10 hours light period	11.02	± .391	8 hours induction for 14 days	25.0	± .369
10 hours light period	10.82	± .359	8 hours induction for 21 days	24.70	± .355
11 hours light period	9.95	± .392	8 hours light period	24.59	± .149
10 hours induction for 21 days	9.82	± .435	11 hours light period	23.4	± .289
8 hours light period	5.89	± .251	10 hours induction for 21 days	22.08	± .259
8 hours induction for 14 days	5.79	± .382	10 hours light period	21.0	± .213
8 hours induction for 21 days	5.74	± .264	10 hours light period	20.42	± .193

N.B.— $\sqrt{2}$ s. t. 5 per cent = 5.195

N.B.— $\sqrt{2}$ s. t. 5 per cent = 2.025

Line across indicates insignificant

TABLE XII

C. olitorius (Sown on 2-6-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
14 hours light period	275.49	± 6.74	14 hours light period	185.09	± 4.29
14 hours induction for 30 days	209.95	± 4.47	14 hours induction for 60 days	91.25	± 8.4
14 hours induction for 14 days	209.44	± 6.27	14 hours induction for 30 days	88.70	± 8.79
14 hours induction for 7 days	203.84	± 6.52	14 hours induction for 14 days	87.70	± 1.26
Normal daily light period	198.85	± 7.29	14 hours induction for 7 days	86.84	± 1.06
10 hours induction for 7 days	186.69	± 6.07	Normal daily light period	86.70	± 2.42
14 hours induction for 60 days	182.64	± 7.61	10 hours induction for 7 days	86.17	± 1.18
12 hours light period	60.1	± 2.07	12 hours light period	39.08	± 6.09
11 hours light period	50.5	± 3.38	8 hours light period	34.17	± 1.29
10 hours induction for 14 days	26.69	± 1.41	11 hours light period	34.0	± 8.43
10 hours induction for 60 days	25.97	± 3.34	10 hours induction for 60 days	28.92	± 1.25
10 hours light period	24.49	± 2.79	10 hours induction for 14 days	28.0	± 5.64
10 hours induction for 30 days	23.09	± 2.29	10 hours light period	27.92	± 1.05
8 hours light period	19.37	± 1.85	10 hours induction for 30 days	27.08	± 7.01

Line across indicates insignificant

N.B.— $\sqrt{2}$ s. t. 5 per cent = 3.78N.B.— $\sqrt{2}$ s. t. 5 per cent = 2.12

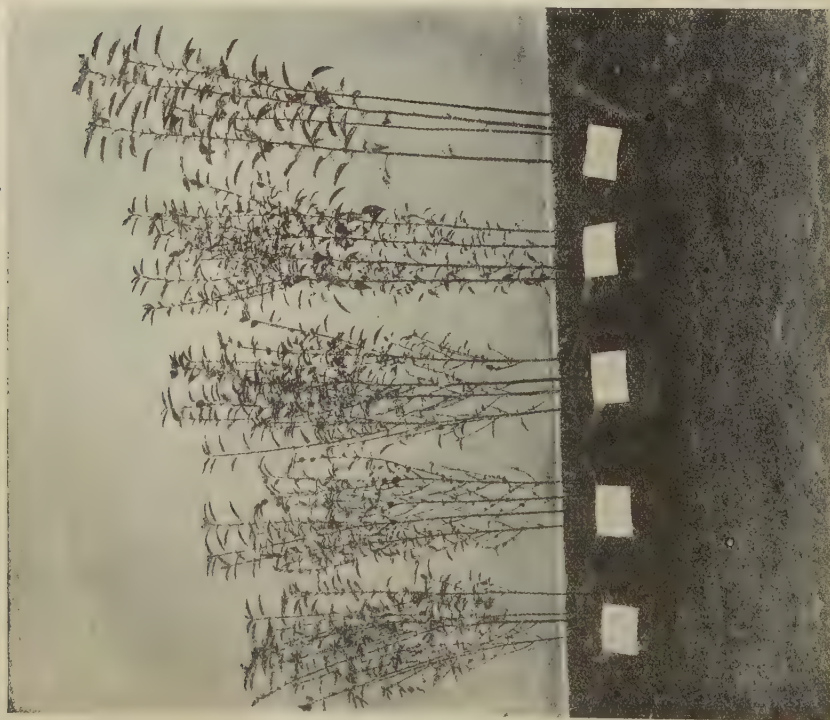


FIG. 1. *C. capsularis* treated under 8, 10, 11, 12 & normal light period. Sown on 17.4.48.
Photographed on 7.7.48.

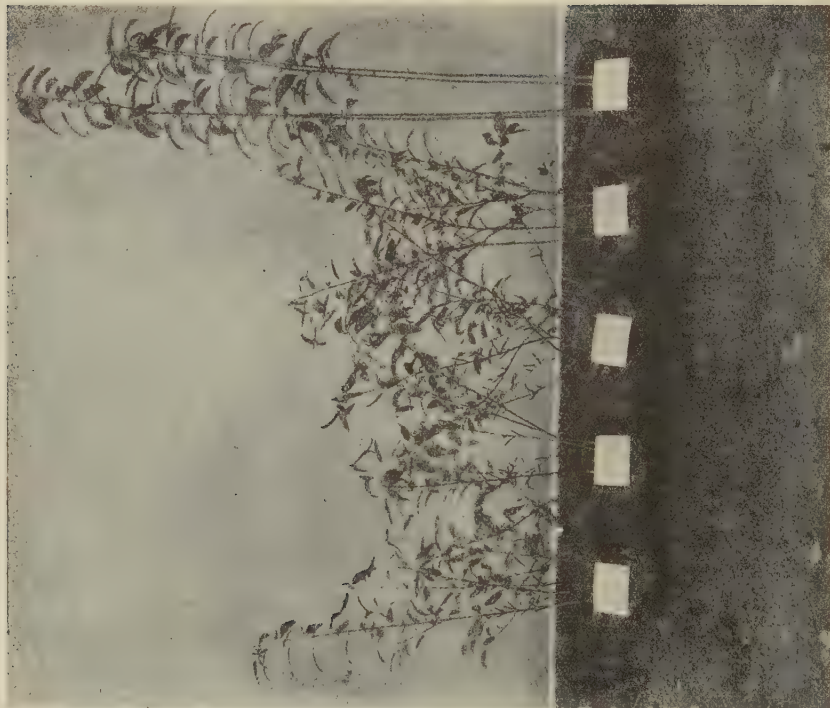


FIG. 2. *C. olitorius* treated under 8, 10, 11, 12 & normal light period. Sown on 17.4.48.
Photographed on 7.7.48.

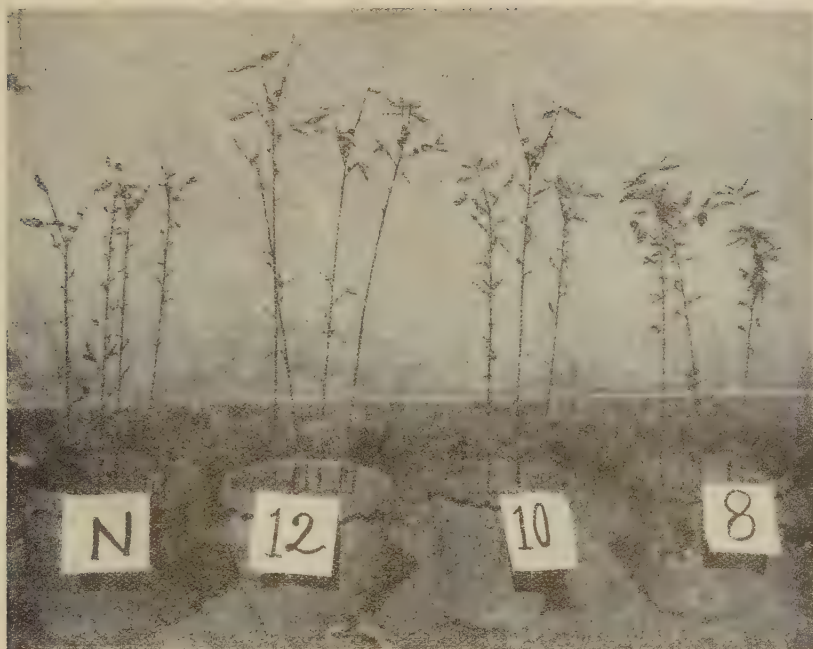


FIG. 3. *C. capsularis* sown on 1-10-48. Photographed on 26-12-48. Short day treatment

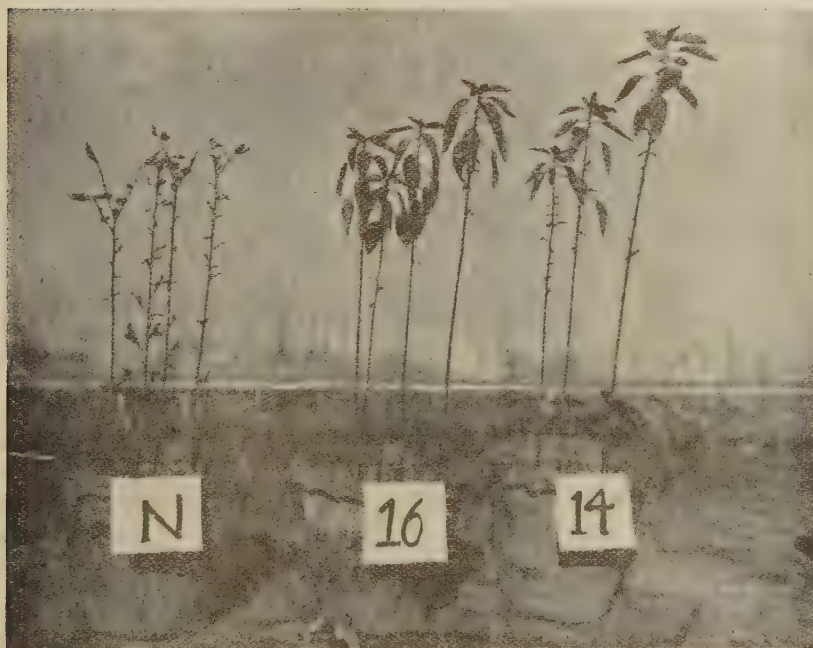


FIG. 4. *C. capsularis* sown on 1-10-48. Photographed on 26-12-48. Long day treatment



FIG. 5. *C. olitorius* sown on 1-10-48. Photographed on 26-12-48. Short day treatment



FIG. 6. *C. olitorius* sown on 1-10-48. Photographed on 26-12-48. Long day treatment

TABLE XIII

C. olitorius, (Sown on 1-10-48)

Mean time of flowering and mean height at flowering in order of magnitude for the different treatments

Treatment	Height on the day of flowering		Treatment	Day of flowering	
	Mean	S.E.		Mean	S.E.
14 hours light period	66.94	±3.49	16 hours light period	84.0	±1.11
16 hours " "	64.44	±4.28	14 hours " "	76.7	±.284
12 hours " "	12.72	±.691	8 hours " "	34.0	±.662
Normal daily light period	11.93	±.561	12 hours " "	32.28	±.776
10 hours light period	9.49	±.846	10 hours " "	31.09	±.948
8 hours " "	8.53	±.491	Normal daily light period	27.2	±.742

N.B. $\sqrt{2}$ s. t. 5 per cent=1.88

N.B. $\sqrt{2}$ s. t. 5 per cent=.645

Line across indicates insignificant

To study the effect of different treatments on the course of vegetative growth, fortnightly readings of height in cm. number of internodes, number of mature leaves on the main stem, number of leaves shed were taken but the data are not presented here. By calculating the average daily increase in height at the reading at flowering and at the reading towards the end of growth it has been found that in the plants treated with short photoperiods the daily increase in height is greater when calculated on the basis of last reading towards the end of growth than at flowering, whereas in the plants treated with long light periods and normal the rate of growth is higher at flowering than towards the end. This was very clearly seen in *C. olitorius*, but in *C. capsularis* this was not clear in the case of 1.10 sowing; the photographs of different treatments are given in plates I—III.

DISCUSSION

This investigation has confirmed the finding of Sen Gupta and Sen [1944, 1946] and of Kar [1944] that both the species of jute behave as short day plants, by treatments with 10 to 12½ hours of light period causing earliness of flowering compared with the plants exposed to the normal light period of the normal flowering season of the plant.

In considering further details of response to photoperiods it should be remembered that for widely separated sowing times between April and July the flowering takes place within the short period between end of August and beginning of September [Sen Gupta and Sen 1943, 1948].

Between the three sowings reported in this, it should be remembered that with the course of growth the plants of 17.4 and 2.6 sowing are exposed to high temperatures (max. 96.5°F.; min. 77.7°F.) and those of 1.10 sowing to lower temperature (90.5°F. max.; 56.9°F. min.). The plants of 2 July 1948 sowing however are exposed to high humidity and rainfall of the monsoon period commencing at comparatively young ages, as compared with 17 April 1948 sowing. The plants of 2 June 1948 sowing are characterized by higher rate of daily growth than the 17 April 1948 sowing and those of 1 October 1948 sowing are characterized by low rate of daily growth and this can be ascribed to the comparatively lower temperature to which the plants of this sowing are exposed. The daily light period is also however much shorter in the 1 October 1948 sowing.

Of the different short light periods tried it is seen that 10 hours light period with 14 hours darkness period is the most favourable combination in both the species, in all the sowings, except 1 October 1948 sowing in which case flowering took place earliest in the normal light period (11 h. 39 min. to 11 h. 29 min.), but closely followed by 10 hrs. in *C. olitorius* and about the same time as 10 and 8 hours treatments in *C. capsularis*.

In 1 October 1948 sowing therefore it seems 11½ hours light period and 12½ hours of darkness period is the most favourable combination. This difference in relative requirement of light and darkness period can be ascribed to the comparatively lower temperature range to which the plants of this sowing are exposed.

Among the different sowings tried it is interesting that in the short light period treatments (8 to 12 hours) the flowering is delayed with the lateness of sowing but in the long light period treatments flowering is delayed with the earliness of sowing. The plants of the three different sowings were exposed to different environmental factors. The mean maximum and minimum temperature of 17 April 1948 sowing (composed of short light period) up to flowering in the short light period treated plant were 93.7°F. and 77.9°F. respectively, the mean relative humidity at 8 a.m. was 79.9 per cent and the hours of bright sunshine of the complete days was 9.0 hours. The same value for 2 June 1948 sowing were 94.9°F. and 81.0°F., 83.4 per cent; and 5.7 hours and for 1 October 1948 sowing they were 90.5°F. and 76.6°F., 90.6 per cent and 6.5 hours. The main differences in the three sowings therefore are the lowest minimum temperature of 1 October 1948 sowing, highest maximum and minimum temperature of 2.6 sowing, highest and lowest bright hours of sunshine in 17.4 sowing and 2.6 sowing respectively, and the highest and lowest relative humidity in the 1.10 and 17 April 1948 sowings respectively. The highest rate of vegetative growth in the 2 June 1948 sowing and lowest rate in 1 October 1948 sowing may be due to highest and lowest temperature ranges in the two sowings respectively. The earliest flowering (in the short day treatments) in 17.4 sowing may be due to the high values of hours of bright sunshine and comparatively dry condition. But it is difficult to ascribe the differences in photoperiodic responses to definite factors more precisely.

In the case of long light period however the delay in flowering in 1 October 1948 sowing compared with 2 June 1948 sowing may be due to lower temperature range in the former.

In general, however, the nature of relative effect of temperature and light period in Jute plants seems to be similar to peas as found by Kopetz [1946], where it is concluded that under short day treatment, the influence of temperature seems to be masked by a stronger effect of day length, but under long photoperiods, temperature seemed to be the determining factor of development.

The fruiting time as also the number of fruits produced were also clearly influenced by the photoperiodic treatments and the sowing time. In the long light period treatments (14 and 16 hours) there was either no fruiting or in rare cases production of undeveloped abortive fruits. In the short light period treatments and normal of all the three sowings, produced normal fruits, but the time of fruiting increased in the similar treatments with the lateness of sowing and this can be ascribed to differences in temperature higher temperature accelerating the fruiting time. The number of fruits produced however was highest in similar treatments of 2-6 sowing and plants of this sowing are characterized by more rapid vegetative growth.

If the influence of different light periods on the fruiting time is considered it is found that in general in all the sowings the time required for initiation of fruits follows the same sequence as the flowering time, i.e., 10 hours light period produced fruits earliest, and otherwise the fruiting time increases with the increase in light period. In the cases of 14 hours and 16 hours treatments as mentioned before no fruits were formed but in the rare cases when they were formed the fruiting time was longer than any of the other light periods tried. It has been found by Eguchi [1937] and Loehwing [1939] that in studying the photoperiodic effects the effective photoperiod which induce early flowering and that which induce early fruiting have to be found out separately and that the photoperiodic response to flowering may be quite different from that to fruiting. From what has been mentioned above it is clear that in jute plants the short photoperiod which induce early flowering is also required for early fruiting. That higher temperature also enhances fruit production is seen from the fact that the largest number of fruits is formed in every treatment in the 2-6 sowing which is exposed to comparatively highest range of temperature within the three sowings. In the experiment on the relative effect of curtailing the light period from the morning and from the evening in the 8 hours and 10 hours treatment, the delay in flowering as also the decreased and disturbed vegetative growth in the sets which were darkened in the morning as compared with those darkened in the evening, show, that when the darkening is done in the morning the normal harmonious growth balance, and perhaps also the nutritional balance, is somehow disturbed.

Experiments on the photoperiodic treatments for different durations from the beginning show firstly, that in the long light treatments even if the duration of the treatments is increased up to 60 days, there is practically no difference in the flowering time.

C. olitorius is much more sensitive to the early period treatments than *C. capsularis*. The Photoinductive cycle in the case of both the species consists of 10 hours light period and 14 hours darkness period and for *C. olitorius* 14 cycles are sufficient to induce earliness of flowering and for *C. capsularis* 21 cycles being necessary. In *C. capsularis* after exposure to 21 cycles it was found that although a few flowers

were produced early they were shed and the plants after further prolonged vegetative growth came to the production of normal flowers leading to the production of fruits about the same time as the plants exposed to the normal daily light periods. It may be said that in this case the amount of the supposed flowering hormone produced had just reached the critical concentration and the internal conditions of the plants so treated is similar to the plants of *C. olitorius* sown on 31 March as mentioned by Sen Gupta and Sen [1947] and the work of Harder [1942] on *Kalanchoe blossfeldiana* and Mayer [1947] in *Sedum* to study the effect of reduced flowering hormone may be mentioned in this connection.

In 8 hours treatment for 14 days and 21 days and 10 hours treatment for 14 days in *C. capsularis* the flowering took place just a few days before the normal plants, and the difference in flowering time is statistically significant. But these plants showed a remarkable acceleration of vegetative growth in that they grow to much greater heights than normal. That they showed earliness in flowering, points to the early production of flowering hormone at the time of short light period treatment and that flowering took place only a few days before the normal, points to indicate that the hormone for vegetative growth was predominant and the comparatively small concentration of the flowering hormone formed could not express itself earlier. The remarkable acceleration of vegetative growth however is difficult to explain. It may be that if the plants are exposed to non-photoinductive cycles after the production of some concentration of flowering hormone by exposure to photoinductive cycles—the flowering hormone is either partly converted into, or stimulate the production of larger quantities of normal auxin of plant growth.

It is now known [Hamner and Bonner 1938, Naylor 1941] that the youngest nature leaves are the chief loci of photoperiodic perception and that young developing and old ones may even inhibit the photoperiodic reaction either by diluting or destroying the substance produced, although the production in the shoot of substance which are antagonistic to sexual reproduction is not accepted by Cajlachjan [1937] and Stout [1945]. In jute it is found that the period of treatment necessary to induce flowering is much shorter in 30 days old plants (*C. olitorius* 10.7 days; *C. capsularis* 13.1 days) than the young seedlings 5 days old (*C. olitorius* 16.0 days; *C. capsularis* 28.6 days); this may be due to the 30 days old plants having a larger number of leaves which perceives the photoperiodic stimulus as found by Berthwick and Parker [1938] in soyabean. The fact that 60 days and 90 days old plants required slightly longer periods of treatments to induce flowering may be due to the relatively greater number of young developing and old leaves which may have an inhibiting effect on the photoperiodic reaction.

If lastly the vegetative growth is considered it will be noted that the plants which were induced to flower early by short photoperiodic treatments had in general a higher rate of growth in height after flowering than before, whereas in the plants treated to long light periods and to the natural daily light period the flowering took place after a much longer period and the daily growth in height was in these cases higher before flowering than after. It seems that the plants induced to flower early had their normal course of vegetative growth inhibited by the shortlight period treatments and

such inhibition has been observed by various workers [M urneck 1936 and 1940, Greulach 1942]. But these plants grew more rapidly after flower initiation, as evidently the normal course of potential vegetative growth which had been inhibited before flowering can now have its natural expression. In the plants of long-light treatments and natural light periods however as the vegetative growth continues for a long period, when the flower initiation takes place, there is no suppression of potential vegetative growth.

Although the plants of short light periods continue to grow after flowering, the decaying changes, associated with shedding of leaves and slowing down of the apical growth and ultimately drying out of the whole plants, set in much earlier than the normal plants. And after flowering the circumference at the base of the stem increased very quickly in the short light period treated plants but as growth did not continue very long in these the plants of the normal light periods developed in the long run much stouter stem. This is in line with the finding of Roberts, and Struckmeyer and others [1927, 1936 and 1946] that the flowering of plants is associated with increased cambial growth and hastening maturity irrespective of the treatment which induces reproductive phase and the age of the plant.

SUMMARY

Two species of jute *C. capsularis* (D 154) and *C. olitorius* (Chinsura green) were subjected to experiments for their response to different photoperiods as follows :

- (a) The influence of continuous treatments of 8, 10, 11 and 12 hours light periods sown on 17 April 1948, 2 June 1948 and 1 October 1948 and in addition to 14 hours and 16 hours light periods in 2 June 1948 and 1 October 1948 sowings.
- (b) Effects of curtailing light period by darkening in the morning and in the evening in the 8 hours and 10 hours light period treatments.
- (c) Effect of treatments of 8, 10 and 14 hours for different period of duration—7 days, 14 days, 21 days, 30 days and 60 days from the beginning.
- (d) The effect of treatment at 10 hours at the ages of 30 days, 60 days and 90 days.

C. olitorius is more sensitive in the flowering response due to photoperiodic treatments than *C. capsularis*.

Both the species are found to behave as short day plants, the 10 hours light period and 14 hours darkness period being found to be the most favourable combination among the treatments tried, to induce earliness of flowering. *C. olitorius* flowered in 21 days against 125.7 days in normal and *C. capsularis* flowered in 33.59 against 130.92 days in normal plants. Earliness in flowering was also observed in treatments of 8, 11 and 12 hours.

Plants darkened in the evening grew better and flowered earlier than those darkened in the morning (in the 8 and 10 hours treatments) in both the species.

Flowering time in the different shortday treatments were delayed with the lateness of sowing in both the species.

Fourteen photoinductive cycles of 10 hours light period and 14 hours darkness periods were sufficient to induce flowering in *C. olitorius* and for *C. capsularis* 21 such cycles were necessary.

Plants treated with long light periods of 14 hours and 16 hours delayed flowering or did not flower at all, and in those that flowered either no fruits or undeveloped abortive fruits were found, in both the species.

Plants of *C. capsularis* treated with 8 hours periods in 14 days and 21 days and for 10 hours periods for 14 days were characterized by unusual increased vegetative growth when sown on 17 April 1948.

Daily growth in height of plants induced to flower early by short photoperiods was lower before and higher after, and of those exposed to normal daily light period and long light periods was higher before flowering and lower after, in both the species.

Induction of flowering was associated with the thickening of the stem followed by the termination of growth.

The probable causes of the nature of responses found are discussed whenever possible.

The differences in the photoperiodic response in the three times of sowing are due to the difference in the environmental factors of which the effect of temperature seems to be the most prominent, in both the species.

The initiation of fruits is influenced by photoperiods and temperature in the same manner as the initiation of flowers, in both the species.

ACKNOWLEDGMENT

Our thanks are due to Sri Anil Sen Gupta, B.A., for the statistical analysis of the data.

REFERENCES

- Allard, H.A. and Garner, W.W. (1940). Further observations on the Response of various species of plants to length of Day. United States, *Agric. Tech. Bull.* 727
- Borthwick, H. A. and Parker, M. W. (1938). Influence of photoperiods upon the differentiation of meristems and the blossoming of Biloxi Soyabeans. *Bot. Gaz.* 99
- Borthwick, H. A. and Parker, M. W. and Seully, N. J. (1943). Effect of photoperiodism and temperature on growth and development of Taraxacum Kok-Saghyz. *Bot. Gaz.* 105, 100-107
- Cajlachjan, M. H. (1937). Hormonal theory of plant development, Moscow, Quoted from *Vernalization and photoperiodism*
- Danielson, L. L. (1944). Effect of day length on growth and development of the Cucumber. *Plant physiol.* 19(4), 638-648
- Dennison, R. A. (1945). Growth and nutrient responses of Little Turkish Tobacco to long and short photoperiods. *Plant physiol.* 20(2), 183-199
- Eguchi, J. (1937). Quoted from *Vernalization and Photoperiodism* 1948. *Proc. Imp. Acad. Japan*, 13, 332-333
- Garner, W.W. and Allard, H.A. (1920). Effect of Relative length of day and night and other factors of the environment on growth and reproduction in plants. *J. agric. Res.* XVIII, 553-606

- Garner, W. W. and Allard, H. A. (1923). Further studies in photoperiodism, the response of plant to relative length of day and night. *J. agric. Res.* **XXIII**, 871-920
- Gertrude Meyer (1927). *Planta, Archivfur Wissenschaftliche Botanik* 35 Bd., $\frac{1}{2}$ Heft.
- Greulach, V. A. (1942). Photoperiodic effects in (2 short day and 4 long day) composites. *Bot. Gaz.* **103**, 269-279
- Gilbert, B. E. (1926). Interrelation of relative day-length and temperature. *Bot. Gaz.* **81**, 1-24
- Hamner, K. C. and Bonner, J. (1938). Photoperiodism in relation to hormones as factors in floral initiation and development. *Bot. Gaz.* **100**, 388-431
- (1944). Photoperiodism in Plant. *Annual Review of Biochem.* **XIII**, 575-590
- Heath, O. V. S. (1943). 'Effects of day length and temperature on onion grown from sets and general discussion, Part 2.'. *Ann. Appl. Biol.* **30**, 308-319
- Heath, O.V.S. and Mathur, P. B. (1944). Inflorescences initiation and development and other changes in the internal morphology of onion sets, as influenced by temperature and day length. *Ann. Appl. Biol.* **31**
- Harder *et. al.* (1942). Quoted from *Vernalization and Photoperiodism* 1948. *Jahrb. Wiss. Bot.* **90**, 546-591
- Kopetz, L. M. (1943). Quoted from *Vernalization and Photoperiodism* 1948. *Gartenbauwiss* **17**, 255-262
- Loehwing, W. F. (1939). Photoperiodic aspect of Phasic development. *Science* **90**, 552-555
- (1948). The developmental physiology of seed plants. *Nature* **107**
- Mann, L. K. (1940). Effect of some environmental factors on floral initiation in *Xanthium*, *Bot. Gaz.* **102**, 339-356
- McKinney, H. H. and Sando, W. J. (1935). Earliness in sexual reproduction in wheat as influenced by Temperature and Light in relation to growth phases. *J. agric. Res.* **LI**, 621-641
- Murneek, A. E. (1936). *Proc. Amer. Soc. Hort.* **34**, 507-509
- (1940). Length of day and Temperature effect in *Rudbeckia*. *Bot. Gaz.* **102**, 269-279
- (1948). Photoperiodism and Vernalization. (a) *History of Research in Photoperiodism*, 39-61. (b) *Nutrition and metabolism as related to Photoperiodism* : **83**, 90
- Naylor, A. W. (1941). Effect of some environmental factors upon photoperiodic induction of Beet and Dill. *Bot. Gaz.* **102**, 557-575
- Purvis O. N. (1934). An analysis of the influence of Temperature during Germination on the subsequent development of certain winter cereals and its relation to the effect of length of day. *Ann. Bot.* **48**, 919-934
- Post, K. (1942). Effects of Daylength and Temperature on Growth and flowering of some florist crops. *NV (Cornell.) Agr. Expt. Sta. Bull.*, 787
- Roberts, R. H. (1927). Relation of composition to growth and fruitfulness of young Apple trees as affected by girdling, shading and photoperiod. *Plant physiol.* **2**, 273-286.
- Roberts, R. H. and Struckmeyer, B.E. (1938). The effect of temperature and other environmental factors upon the photoperiodic responses of some of the higher plants. *J. agric. Res.* **ivi.**, 633-678
- (1939). Further studies of the effect of temperature and other environmental factors upon the photoperiodic response of plants. *J. agric. Res.* **lix**, 699-709
- (1946). The effect of Top Environment and flowering upon Top-Root ratios. *Plant Physiol.* **21**, 332-344
- Roberts and Wilton, O. C. (1936). Correlation of combial activity on flowering and regeneration. *Bot. Gaz.* **99**, 854-864
- Struckmeyer, B. E. (1946). The anatomy of the abnormal seedlings on the stem of some varieties of soyabbeans. *Amer. J. Bot.* **34**, 571-577

- Sen, N. K. and Pain, S. K. (1948). Photoperiodic effect of Sesamum in relation to the variation of the environmental factors of the different seasons. *Proc. Nat. Inst. Sci. India*
- Sen Gupta, J. C. and Sen, N. K. (1943-44). Physiology of Jute. *Sci. Cult.* IX
- (1944). On photoperiodic effect of Jute. *J. Ind. agric. Sci.* **14**, 196-202
- (1946). Photoperiodism in Jute. *Nature*, **157**, 655-656
- (1947). Investigation on the cause of early flowering in Jute (*C. olitorius*) sown in March. *J. Ind. Bot. Soc.* **26** : 41-49
- (1948). Effect of sowing time on growth and development of jute—I. *Bull. Bot. Soc., Bengal*, **2**, 41-49
- Sen Gupta, J. C. and Sen, G. (1950). Effect of shortening the daily light period in the morning and in the evening, in short-day treatment of Jute. (i) *Cur. Sci.* **19**, 184-185
- (1950). (ii) Photoperiodic induction in Jute and a great acceleration of vegetative growth in *C. Capsularis*. *Nature*, 22 July 152-153
- (1950). (iii) *Sci. Cult.* **16**, 119
- Snyder, W. E. (1940). Effect of light and temperature on floral initiation in Cocklebur & Biloxy Soyabean. *Bot. Gaz.* **102**, 302-322
- Steinberg, R. H. and Garner, W. W. (1936). Response of certain plants to length of day and temperature under controlled conditions. *J. agric. Res.* liii, 943-960
- Stout, M. (1945). Translocation of the reproductive stimulus in sugar beet. *Bot. Gaz.* **107**, 86-96

ROLE OF LEGUMES AND GREEN MANURING IN MIXED FARMING HOLDINGS

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(Received for publication on 2 February 1951)

MIXED farming is a system where crop and animal production operate in support of each other. The animal supplies manure to enrich the soil leading to the increase of the production of food for human beings and feeds and fodders for cattle. Since the cropping system in mixed farming always includes some fodder humes and pulse crops, soil fertility is further protected from depletion, because these crops add to the soil nitrogen, which is fixed from the air. After their removal to burial, they leave or add organic matter, well supplied with nitrogen, from which supplies of plant food become steadily available to the following crops.

In India nearly every cultivator practises to some extent a system of mixed farming. He maintains cows and buffaloes and tries to breed his own work cattle and obtains milk and dairy products, the extent depending on the size of his holding and other facilities available. The size of the economic holding or, as we may call it, the family farm, varies from area to area, from village to village and from house to house. For instance, in a single district of Ferozepore (Punjab), the average holding is eight acres in the riverain country of Sutlej and 92 acres on the borders of Bikaner (2). In the Lyallpur district (Pakistan) the average size of the holding is 18 acres. Cereals predominate in the cultivation; and of cereals in the Northern India, the most important is wheat. The peasant's first care is to grow wheat and as maize also forms part of his diet, he grows both where possible. When it is realized that 80 to 90 per cent of the holdings in India are below 10 acres, the predominance of cereals is explained. The cultivation of cereals on innumerable small holdings is leading day by day to unprogressive farming and a low standard of living, as a sound system of manuring and cropping is absent. The maintenance of soil fertility is of great importance to the cultivator, for unless a system of cropping and manuring is adopted which will return a sufficient proportion of what is taken from the soil, yields must gradually drop.

Small scale mixed farming experiments started at the Indian Agricultural Research Institute Farm in 1941-42 have a direct bearing on the problem of keeping the soil fertility at a high level. Three mixed farming holdings were laid out in Main Block Nos. 6, 3 and 2 under irrigated conditions. The area under the first and the second holdings was 8 acres each and 7.5 acres under the third holding. Holding No. II was green manured once in two years and holding No. III was green manured twice in three years and no green manuring was practised in holding No. I where some land was kept fallow and *kharif* legume fodder was grown as against green manure in the other two holdings. The object of the experiment was:

- (i) to maintain the soil fertility at a high level as determined by the yield of crops per acre;

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- (ii) to find out if it was advisable to green manure a small holding once in two years or twice in three years or to keep a portion of the holding fallow and grow a legume fodder ;
- (iii) to compare the production of crops under the three systems of cropping and manuring ; and
- (iv) to produce enough food for a family of five members equivalent to 4.3 adult units and feeds and fodders for five livestock.

System of cropping adopted

Holding No. I. Area : 8.0 acres (Main Block No. 6). Appendix A gives the cropping scheme followed from 1941-42 to 1948-49. During the first two years no definite rotation was followed. In 1943-44 the area was divided into four blocks, each representing one year of the 4-year rotation.

Rotation :

- (1) Cowpea followed by barley
- (2) *Jowar* fodder followed by peas
- (3) Fallow followed by wheat or wheat and oats
- (4) Maize followed by peas and berseem green fodder.

Ten tons of farmyard manure was applied to maize every year.

Holding No. II. Area : 8 acres (Main Block No. 3). Appendix B gives the cropping scheme followed from 1941-42 to 1948-49. The area was divided into two blocks of 4 acres, each representing one year of the 2-year rotation which was adopted.

Rotation :

- (1) Sannhemp green manure followed by wheat and barley
- (2) (i) Maize and *arhar* sown mixed
- (ii) *Jowar* fodder followed by gram and/or peas
- (iii) Cotton

Arhar and cotton were discarded in 1945-46 and 1946-47 respectively in favour of maize and the two-year rotation adopted was :

<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>
Green manure	Cereal	Cereal and millet fodder	Legume in the following two parts
(i) Sannhemp green manure	Wheat	Maize	Peas and berseem green fodder
(ii) Sannhemp green manure	Wheat Barley	<i>Jowar</i> fodder	Peas

Ten tons of farmyard manure was applied to sannhemp before sowing.

Holding No. III. Area : 7.5 acres (Main Block No. 2). Appendix C gives the cropping scheme followed over a period of 8 years from 1941-42 to 1948-49. The

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ROLE OF LEGUMES AND GREEN MANURING, ETC.

7.5-acre unit was divided into three blocks, each representing one year of the 3-year rotation which was adopted.

Rotation :

- (1) Sannhemp green manure followed by wheat
- (2) (i) Maize and *arhar*
(ii) *Jowar* fodder followed by gram and/or peas
(iii) Cotton

- (3) Sannhemp green manure followed by wheat and barley

Arhar and cotton were discarded in 1945-46 and 1946-47 respectively and the 3-year rotation operated as follows :

Sannhemp green manure—cereal—cereal—legume—sannhemp green manure—cereal and millet fodder in the following two parts :

<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>
(i) Sannhemp	Wheat	<i>Jowar</i> fodder	Peas	Sannhemp	Wheat
(ii) Sannhemp	Barley	Maize	Berseem fodder	Sannhemp	Wheat

Ten tons farmyard manure was applied to sannhemp before sowing.

The rotations followed in the three holdings and described above are summarised below :

<i>Summary of the rotations adopted</i>							
<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>
<i>Holding No. I</i>							
Legume	Cereal	Millet fodder	Legume	Fallow	Cereal	Cereal	Legume
<i>Holding No. II</i>							
Green manure	Cereal	Cereal and millet fod- der	Legume				
<i>Holding No. III</i>							
Green manure	Cereal	Cereal and millet fod- der	Legume	Green manure cereal			

Intensity of cropping

Table I gives the acreage of cropped areas (excluding green manuring) and the intensity of cropping under each holding over a period of eight years. The details of acreage under different crops are given in Appendices A, B and C.

TABLE I
Intensity of cropping

Year	Holding No. I		Holding No. II		Holding No. III	
	Cropped area acres	Cropping intensity per cent	Cropped area acres	Cropping intensity per cent	Cropped area acres	Cropping intensity per cent
1941-42	13.0	162.5	10.0	125.0	9.0	120.0
1942-43	13.5	168.8	10.5	131.3	9.3	123.3
1943-44	12.8	159.4	10.0	125.0	9.0	120.0
1944-45	12.0	150.0	10.0	125.0	9.0	120.0
1945-46	13.0	162.5	11.0	137.5	9.5	126.7
1946-47	13.0	162.5	12.0	150.0	9.5	126.7
1947-48	14.0	175.0	12.0	150.0	10.0	133.3
1948-49	14.0	175.0	12.0	150.0	10.0	133.3
Average		164.5		136.8		125.4

It is thus seen that the intensity of cropping is highest in holding No. I varying from 150.0 to 175.0 per cent ; in holding No. II, it is medium varying from 125 to 150 per cent and it is least in holding No. III from 120 to 133.3 per cent over a period of eight years. The bottom row of Table I gives the average cropping intensity of eight years under each holding. It is found that the average annual cropping intensity of 164.5 per cent, 136.8 per cent and 125.4 per cent have been practised in holding Nos. I, II and III respectively.

Season

In Delhi, a marked distinction between the dry and wet seasons exists. Sowing of crops is not possible throughout the year. The cropping season may be said to start in June and July with the break of the monsoon and the rainy season lasts with varying intensity, until the middle of September. Normally October, November and December are the dry months and in January, February and March slight winter rains may be expected. The following table gives the distribution of rainfall throughout the year for the duration of the experiment.

TABLE II

Rainfall in inches

Month	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	Average
June	2.8	1.8	1.8	4.2	0.7	4.4	..	1.0	2.1
July	..	8.6	6.6	11.4	7.3	6.4	2.5	7.1	6.2
August	3.8	5.1	2.6	1.2	6.0	4.0	4.6	9.1	4.6
September	1.8	6.9	5.0	7.7	10.6	2.1	12.4	4.1	6.3
October	..	..	..	2.6	0.3	0.1	0.4	0.5	0.5
November	..	..	..	..	..	..	..	..	..
December	0.3	0.7	..	..	..	0.4	0.3	..	0.2
January	0.5	0.3	1.0	1.1	..	0.4	1.9	0.1	0.7
February	1.7	..	2.7	..	0.9	0.6	1.0	0.6	0.9
March	..	..	1.9	..	..	1.0	1.0	0.2	0.5
April	0.6	0.4	1.4	0.2	..	..	..	..	0.3
May	0.2	0.7	..	0.3	0.7	0.6	0.5	..	0.4
<i>Total</i>	11.7	24.5	23.0	28.7	26.5	20.0	24.6	22.7	22.7

CROP YIELDS

The yields obtained during eight years of the experiment are given in Appendices A, B and C.

In order to trace the fertility status of the land under the three holdings, Table III is presented below showing the yields of four main crops grown throughout the period of the experiment. They are wheat, barley, maize and *jowar*.

TABLE III

Yields of crops in maunds per acre

Year	Wheat (grain)			Barley (grain)			Maize (grain)			Jowar (green fodder)		
	Holding			Holding			Holding			Holding		
	I	II	III	I	II	III	I	II	III	I	II	III
1941-42	12.9	11.2	12.4	16.6	26.1	30.8	14.6	10.7	9.2	206.0	437.3	375.9
1942-43	15.5	29.0	28.9	19.7	41.6	40.7	14.9	15.5	24.2	197.5	205.5	242.2
1943-44	18.1	15.8	21.8	13.8	17.1	26.9	13.0	25.8	14.3	140.3	220.7	304.3
1944-45	25.6	38.0	39.0	25.0	44.0	37.3	13.9	37.6	17.1	246.9	349.5	169.4
1945-46	27.8	32.7	28.8	33.2	35.7	38.7	9.6	22.2	13.9	335.4	292.0	308.3
1946-47	18.0	25.0	25.0	26.2	37.5	40.0	14.1	18.0	21.2	384.0	318.5	357.8
1947-48	22.0	23.1	26.7	15.9	33.9	31.3	14.0	9.2	15.2	267.5	301.6	290.9
1948-49	22.0	33.9	28.4	22.5	32.6	35.5	18.9	8.2	18.0	247.4	218.0	282.0
<i>Mean</i>	20.2	26.1	26.4	21.6	33.6	35.2	14.1	18.4	16.6	253.1	292.9	266.3
Yield represented as per cent on holding No. I.	100.0	128.9	130.4	100.0	155.3	162.7	100.0	130.2	117.7	100.0	115.7	105.2

Fisher's 't' test was applied to the yields of wheat, barley, maize and jowar to judge the significance of the differences between any two of the rotations.

The following results were obtained :

	Mean difference (md. per acre)	Significance
Wheat		
Holdings I and II	5.9	Significant at 5 per cent level
Holdings I and III	6.1	Significant at 1 per cent level
Holdings II and III	0.3	Not significant
Barley		
Holdings I and II	11.9	Significant at 1 per cent level
Holdings I and III	14.5	do.
Holdings II and III	1.6	Not significant
Maize		
Holdings I and II	4.3	Not significant
Holdings I and III	2.5	do.
Holdings II and III	1.8	do.
Jowar		
Holdings I and II	43.0	Not significant
Holdings I and III	38.3	do.
Holdings II and III	26.6	do.

From the above results and examination of the figures given in Table III it is seen that the yields have kept up fairly well in all the three holdings and there are no definite signs of soil exhaustion. There is no doubt, however, that yields in the green manured holdings are substantially higher than those obtained in the holding where green manuring has not been done. The average yield of wheat per acre is 20.2 maunds where it follows fallow in holding No. I and 26.1 maunds and 26.4 maunds per acre in holding Nos. II and III respectively. Thus a significant increase of 28.9 per cent and 30.4 per cent in the yield of wheat per acre has been effected through the practice of green manuring in holding Nos. II and III respectively over that obtained in holding No. I. In the case of barley, the average yield per acre in holding No. I is 21.6 maunds where the crop follows cowpea green fodder, whereas yields of 33.6 maunds and 35.2 maunds per acre have been obtained in holding Nos. II and III respectively, where barley has been green manured, thereby effecting a significant increase of 55.3 per cent and 62.7 per cent respectively in the yield of the crop. Small increases have been effected in the yield of maize grain and jowar fodder in holding Nos. II and III where these crops are unmanured and follow cereals

over those obtained from holding No. I where *jowar* follows legume and maize follows cereal and is manured directly. These differences in maize and *jowar* are not significant.

Comparing the yields of crops in holding Nos. II and III, it was found that the differences in yields of all crops, wheat, barley, maize and *jowar*, were not significant.

ECONOMICS OF HOLDINGS

The results of these experiments have a bearing on the current problems of agriculture; they not only provide data on the general question of crop yields but also whether the size of the holding (7.5—8 acres) is suitable for a farmer and his family and further as to the economic returns obtained by him for the labour he would have to devote to his holding.

For purposes of discussion, the peasant's household may be considered to consist of himself, his wife, two sons of 17 and 12 years and a daughter of 10 years' age. It may further be assumed that the peasant and his son (17 years) will be mainly concerned with field operations and looking after the bullocks, younger son (12 years) will attend the school and wife and daughter will look after the milch animals and young stock. The strength of cattle on each holding has been taken as consisting of one pair of bullocks, one milch cow and two young stock.

The farmer's family has been converted into adult units according to the standards set by the nutrition experts (1 and 3) as follows:

<i>Individual</i>	<i>Proportion</i>
Peasant	1.0
Wife	0.8
Son (17)	1.0
Son (12)	0.8
Daughter (10)	0.7
<i>Total</i>	<u>4.3</u>

Consumption

The annual requirements of this family unit for food and of livestock for feeds and fodders are calculated roughly as follows:

	<i>Consumption per annum in maunds</i>		
	<i>Cereals</i>	<i>Pulses</i>	<i>Oil-cake</i>
I. Consumption of the family at 15 oz. of cereals and 3 oz. pulses.	18.0	3.5	..
II. Concentrates for livestock*			
(i) 1 pair of bullocks consuming 4 lb. of grain per day	9.1	9.1	18.3

* As per feeding schedule followed at the Indian Agricultural Research Institute Farm.

II. Concentration for livestock—*contd.*

(ii) 2 young stock consuming $1\frac{1}{2}$ lb. of grain per head per day.	6.8	2.7	4.1
(iii) 1 cow producing 5,000 lb. of milk annually will be fed 1 lb. of concentrates for 2 lb. of milk produced.	15.3	6.1	9.2
III. Seed requirements	6.0	4.9	..
Total grain and oil-cakes required for feeding the family and livestock per annum.	55.1	25.4	31.5

IV. Fodder requirement for livestock*

Maunds

(i) Green fodder at 15 seers per adult cattle per day	597.5
(ii) Dry fodder at 6 seers per adult cattle per day	219.0

. *Production and balance left after consumption*

Average annual production of grain and fodder from the three holdings and the balance left after consumption are given below in Table IV.

TABLE IV

Average annual production of grain and fodder and balance left after consumption

Items of production	<i>Holding No. I</i>		<i>Holding No. II</i>		<i>Holding No. III</i>	
	Production	Surplus or deficit	Production	Surplus or deficit	Production	Surplus or deficit
	md.	md.	md.	md.	md.	md.
Cereals	105.9	+50.7	129.7	+74.6	150.7	+95.5
Pulses	43.3	+17.9	38.1	+12.7	28.9	+3.4
Green fodder	1,099.4	+501.9	739.3	+131.8	584.2	—13.3
Dry fodder	218.5	—0.5	243.5	+24.5	262.3	+43.3
Cotton	1.8	+1.8	5.8	+5.8	3.4	+3.4

* As per feeding schedule followed at the I. A. R. I farm

For feeding livestock, it is possible to exchange equal quantity of wheat and maize with oats, if so desired. The cost of oil-cake can also be met from the sale proceeds of the surplus produce. It is seen that the produce from all the three holdings normally provides sufficient food for the family, feeds and fodders for the cattle under consideration and leaves a favourable balance to meet the cash requirements of the family.

Labour requirement for crop production

An attempt has been made to see whether the labour requirements for such holdings are within the means of the cultivator. It is not possible to calculate the labour needed directly from these experiments, as full use has been made of mechanical and animal power of the farm in cultivating the land. The figures given below of man-days and bullock-days per acre can be taken as fairly accurate for the purposes of estimating the labour requirement on these holdings. These figures have been taken from the *Cost of Production of Crops in the Punjab* (4 and 5) and represent the average amount of labour expended on the cultivation of different irrigated crops per acre.

TABLE V

Average number of man-days and bullock-days per acre

<i>Crop</i>	<i>Man-days</i>	<i>Bullock-days</i>
Wheat, barley and oats	20.0	8.9
Maize	24.5	6.4
Pulses	11.8	4.6
Cotton	12.7	4.3
<i>Kharif</i> fodders	8.9	3.7
Berseem	50.9	11.8
Sannhemp green manure	7.3	4.0

Table VI gives the number of man-days and bullock-days calculated from Table V and Appendices A, B and C, which are required to cultivate the three holdings from year to year.

TABLE VI

Labour requirements

Year	Holding No. I		Holding No. II		Holding No. III	
	Man-days	Bullock-days	Man-days	Bullock-days	Man-days	Bullock-days
1941-42	213.9	78.2	181.5	78.0	183.0	81.9
1942-43	230.0	83.6	187.4	80.3	187.3	83.0
1943-44	227.8	81.1	181.5	78.0	183.0	81.9
1944-45	208.3	76.9	181.5	78.0	183.0	81.9
1945-46	250.2	89.4	199.6	83.5	192.1	84.6
1946-47	242.0	85.1	262.3	97.4	236.9	91.4
1947-48	250.9	88.8	262.3	97.4	243.0	95.2
1948-49	250.9	88.8	262.3	97.4	243.0	95.2
Mean	234.2	84.0	214.8	86.3	206.4	86.2

From Table VI it is clear that the number of bullock-days expended is almost the same in each of three holdings. Manual labour requirement of holding Nos. II and III is almost the same but in holding No. I it is higher by 19.5 and 27.9 man-days than that of holding Nos. II and III respectively. If the peasant and his elder son each puts in 104 to 118 days a year, they will provide the necessary manual labour for the holdings under discussion. So from the analysis of labour requirement and its supply it is indicated that the family can manage the farm without employing any outside labour.

DISCUSSION

The acreage under different crops in the three holdings was modified from year to year in the beginning in the light of experience gained from the progress of the experiment. The main criteria of the rotations was based on no green manuring, green manuring once in two years and green manuring twice in three years and these were followed rigidly throughout the course of the experiment. In all the holdings were included legumes for fodder and seed, and in holding No. I, *kharif* fallowing featured against green manuring practised in holding Nos. II and III. From the yield results, it is evident that the effect of green manuring on the succeeding crops like wheat and barley has been more significant than that of fallowing and growing of *kharif* fodder legume, i.e., cowpeas. Even fodder *jowar* and maize grain which followed *rabi* cereals in the green manured holdings and barley and peas in the non-green manured holding show that the fertility built up by green manuring was

not totally exhausted by the succeeding *rabi* cereals, but has been responsible for slight increase in the yields of *jowar* and maize over those of the non-green manured holding. The differences between green manuring once in two years and twice in three years, as judged from the yields of wheat and barley, have not been significant, though the latter practice showed slight increase over the former. The trend of yields of all crops shows that there is no deterioration in the fertility of the land under the systems of cropping adopted in the three holdings. The rotations can be adopted according to the local conditions without upsetting the underlying principles followed in the systems.

The economics of the holdings have been worked out taking into consideration the standards arrived at elsewhere under similar conditions. It was neither possible to work the holdings with a cultivator and members of his family and the scheduled number of work cattle, nor actually feed the cultivator and his family and livestock from the produce of the holdings. The holdings were cultivated like other fields of the farm with tractors supplemented by farm bullocks and farm labour. From the analysis of the yield data, it is found that there is a surplus of produce after meeting the feeding requirements of the cultivator's family and cattle scheduled to be maintained on the holdings. Further, the labour requirements in respect of men and work cattle can be met from the scheduled number of head fixed per holding. Taking into account that a better standard of cultivation was given to the holdings by tractors, etc., than would have been possible with the limited resources of an average cultivator, the surplus produce gives an indication of the soundness of the system adopted for the working of the holdings.

It will thus be seen that on each of the holdings the cultivator and his family can be provided with all they require in the way of food without depleting the soil fertility and also left with a surplus produce. It is not unreasonable to accept that the peasant and his son and the pair of bullocks can each put in 100 days a year i.e., two days a week, for earning wages elsewhere which would bring in extra income.

SUMMARY AND CONCLUSIONS

Small scale mixed farming experiments were conducted at the Indian Agricultural Research Institute Farm, New Delhi, with the undermentioned objectives :

(a) To maintain soil fertility by green manuring, growing of fodder legumes and fallowing and (b) to work out the economics of farming of small holdings.

Holding No. I (8 acres), holding No. II (8 acres) and holding No. III (7.5 acres) were put under 4-year, 2-year and 3-year rotations respectively. The average intensities of cropping practised were 164.5 per cent in holding No. I, 136.8 per cent in holding No. II and 125.4 per cent in holding No. III. In holding No. I fallowing and growing of fodder legumes were practised as against green manuring in the other two holdings. Holding No. II was green manured once in two years while holding No. III was green manured twice in three years.

The yields of wheat and barley obtained from the green manured holdings were substantially higher than those obtained from the holding where fallowing and growing of legumes were practised. The difference in yields per acre were found to be

statistically significant. In the case of maize and *jowar*, though the yields obtained in the green manured holdings were higher than the non-green manured holding, the differences were not significant. The differences in yields per acre obtained from the two green manured holdings were not significant.

The outturn of grain in the green manured holdings was higher than that in the non-green manured holding.

The family can provide labour required for farming the holdings.

The total production of grain and fodder from all the three holdings was found to meet the requirements of a small family of 4.3 adult units and that of five livestock. A surplus produce was also left over after meeting the above requirements.

The total yields obtained during the period of the experiment from holding No. II (green manured once in two years) and holding No. III (green manured twice in three years) were not significantly different, and it is therefore indicated that a higher intensity of green manuring is not commensurate with the extra expenditure involved. Between holding No. I (not green manured) and holding No. II (green manured once in two years), the total yields of cereal, dry fodder and cash crop were higher in the latter than in the former, whereas those of pulses and green fodder were higher in the non-green manured holding due to larger acreage under these crops in holding No. I. As the quantity of pulses and fodder obtained from holding No. II was sufficient in meeting the cultivator's requirements, it is advisable to include green manuring which gave a better outturn of cereals and maintained the fertility of the land better than that in the non-green manured holding.

ACKNOWLEDGMENTS

Our acknowledgments are due to Mr C. H. Parr and Mr R. D. Bose under whose supervision and guidance these experiments were conducted and to Dr T. J. Mirchandani for guidance at the later stage of the experiment and suggestions. Our acknowledgments are also due to Mr R. D. Verma for the supervision of the experiments in 1948-49. We thank Messrs Niranjana Singh, Alfred Ram, Waryam Singh and Sardar Ali who helped in the conduct of the experiments. We also wish to express our indebtedness to the late Sardar Arjan Singh who was responsible for the lay out and conduct of the experiments in the initial stage.

REFERENCES

- Aykroyd, W. R. (1937). *Hlth. Bull.* (India), No. 23, 2 and 13
Darling, M. L. (1927). The Economic Holding or the Family Farm. *Agric. J. India*, 22, 399-410
Neil, L. J. (1930). *Dietetics in Warm Climates*. Harrison and Sons, 1930
Singh, K. (1934). Cost of Production of crops in the Punjab 1927-28 to 1931-32. *Bd. Econ. Enquiry, Punjab*, 33
Singh, L. and Singh, A. (1942). Cost of Production of Crops on a Canal irrigated Estate in the Punjab 1935-36 to 1939-40, *Bd. Econ. Enquiry, Punjab*, 83

APPENDIX A

Average and yield of crops grown in mixed farming holding No. I without green manuring

Crops	1941-42		1942-43		1943-44		1944-45		1945-46		1946-47		1947-48		1948-49		Total area in acres	Total yield in md.
	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.		
Wheat	3.0	38.7	3.0	46.4	1.8	31.7	1.0	25.6	3.0	83.4	1.0	18.0	1.0	22.0	1.0	22.0	14.8	287.8
Barley	0.5	8.3	0.5	9.9	2.0	27.6	2.0	50.0	2.0	66.4	2.0	52.4	2.0	31.8	2.0	45.0	13.0	291.3
Oats	..	..	..	..	..	..	1.0	17.7	..	..	1.0	26.9	1.0	24.3	1.0	37.8	4.0	106.6
Maize	0.5	7.3	0.5	7.4	1.5	19.4	0.5	13.9	2.0	19.2	2.0	28.2	2.0	28.0	2.0	37.8	11.0	161.3
Arhar	..	..	0.5	12.4	0.5	6.0	0.5	2.0	..	..	..	..	..	..	..	..	2.0	20.3
Gram	1.5	6.7	2.0	20.6	..	..	..	..	..	..	..	..	..	..	..	..	3.5	27.3
Peas	..	..	..	..	2.0	38.1	2.0	52.3	2.0	43.5	3.0	19.3	3.0	33.4	3.0	68.1	15.0	254.6
Cowpea	..	..	3.5	44.1	..	..	..	..	..	..	..	..	..	..	..	..	3.5	44.1
Jowar (green fodder)	1.5	309.0	1.5	296.3	2.0	280.6	2.0	493.7	1.0	335.4	2.0	768.0	2.0	534.9	2.0	494.8	14.0	3512.6
Guar (green fodder)	3.0	177.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3.0	177.8
Lucerne or Berseem (green fodder)	1.0	291.6	1.0	578.7	1.0	301.0	1.0	288.3	1.0	293.3	1.0	184.7	1.0	675.0	1.0	683.5	8.0	3296.1
Cowpea (green fodder)	0.5	67.3	..	..	2.0	398.5	2.0	300.4	2.0	256.0	1.0	178.4	2.0	319.5	2.0	288.5	11.5	1808.5
Cotton	1.0	5.5	1.0	8.6	..	..	..	..	..	..	..	..	..	..	..	..	2.0	14.1
Dry fodder	5.5	93.7	9.5	210.0	7.3	170.6	6.5	223.5	9.0	311.3	9.0	208.7	9.0	220.2	9.0	310.3	64.8	1748.2
Summary																		
Cereals	4.0	54.3	4.0	63.7	5.3	78.7	4.5	107.2	7.0	168.9	6.0	125.5	6.0	106.1	6.0	142.6	42.8	847.0
Pulses	2.0	6.7	6.0	77.1	2.5	44.1	2.5	54.2	2.0	43.5	3.0	19.3	3.0	33.4	3.0	68.1	24.0	346.3
Green fodder	6.0	845.6	2.5	875.0	5.0	980.7	5.0	1082.4	4.0	884.7	4.0	1131.1	5.0	1529.4	5.0	1466.8	36.5	8795.0
Dry fodder	5.5	93.7	9.5	210.0	7.3	170.6	6.5	223.5	9.0	311.3	9.0	208.7	9.0	220.2	9.0	310.3	64.8	1748.2
Cash crop (cotton)	1.0	5.5	1.0	8.6	..	..	..	..	..	..	..	..	..	..	..	..	2.0	14.1

APPENDIX B
Acreage and yields of crops grown in mixed farming holding No. II with 50 per cent
intensity of green manuring

Crops	1941-42		1942-43		1943-44		1944-45		1945-46		1946-47		1947-48		1948-49		Total area in acres	Total yield in md.
	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.		
Wheat	3.0	33.6	3.0	86.9	3.0	47.5	3.0	114.0	3.0	98.2	3.0	75.0			3.0	101.6	24.0	626.1
Barley	1.0	26.1	1.0	41.6	1.0	17.1	1.0	44.0	1.0	35.7	1.0	37.5	1.0	33.9	1.0	32.6	8.0	268.4
Maize	0.5	10.7	0.5	7.8	0.5	12.9	0.5	18.8	1.0	22.2	2.0	35.9	2.0	18.4	2.0	16.5	9.0	143.2
Arhar	0.5	..	0.5	10.4	0.5	7.3	0.5	2.4	..	..	..	..	..	..	..	..	2.0	20.2
Gram	1.0	9.2	1.5	13.6	..	..	..	..	..	..	..	..	..	..	..	..	2.5	22.8
Peas	1.0	20.7	1.0	18.5	2.0	21.6	2.0	28.9	3.0	40.8	3.0	36.6	3.0	45.3	3.0	49.3	18.0	261.6
Jowar (green fodder)	2.0	874.6	2.0	411.0	2.0	441.5	2.0	699.0	2.0	584.0	2.0	637.0	2.0	603.1	2.0	436.0	16.0	4686.1
Berseem (green fodder)	..	..	..	..	..	..	..	..	..	..	1.0	300.0	1.0	456.3	1.0	472.0	3.0	1238.3
Cotton	1.0	8.6	1.0	10.6	1.0	5.8	1.0	10.6	1.0	11.1	..	..	..	..	..	..	5.0	46.6
Dry fodder	6.5	143.7	7.0	242.2	6.5	147.6	6.5	308.2	8.0	291.5	9.0	286.1	9.0	241.3	9.0	287.6	61.5	1948.2
Summary																		
Cereals	4.5	70.5	4.5	136.2	4.5	77.5	4.5	176.8	5.0	156.1	6.0	148.4	6.0	121.5	6.0	150.7	41.0	1037.6
Pulses	2.5	29.9	3.0	42.5	2.5	29.0	2.5	31.3	3.0	40.8	3.0	36.6	3.0	45.3	3.0	49.3	22.5	304.6
Green fodder	2.0	874.6	2.0	411.0	2.0	441.5	2.0	699.0	2.0	584.0	3.0	637.0	3.0	1059.4	3.0	909.0	19.0	5914.4
Dry fodder	6.5	143.7	7.0	242.2	6.5	147.6	6.5	308.2	8.0	291.5	9.0	286.1	9.0	241.3	9.0	287.6	61.5	1948.2
Cash crop (cotton)	1.0	8.6	1.0	10.6	1.0	5.8	1.0	10.6	1.0	11.1	..	..	..	..	..	..	5.0	46.0

APPENDIX C

Acreage and yields of crops grown in mixed farming holding No. III with 66.6 per cent intensity of green manuring

Crops	1941-42		1942-43		1943-44		1944-45		1945-46		1946-47		1947-48		1948-49		Total area in acres	Total yield in md.
	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.	Area in acres	Yield in md.		
Wheat	4.0	49.6	4.0	115.6	4.0	87.1	4.0	155.8	4.0	115.1	3.5	87.6	4.0	106.9	4.0	113.4	31.5	831.0
Barley	1.0	30.1	1.0	40.7	1.0	26.9	1.0	37.3	1.0	38.7	1.0	40.0	1.0	31.3	1.0	35.5	8.0	231.2
Maize	0.3	4.6	0.3	6.1	0.3	7.1	0.3	8.6	0.5	6.9	1.3	26.5	1.0	15.2	1.0	18.0	4.8	93.0
Arhar	0.3	..	0.3	5.7	0.3	3.2	0.3	1.1	..	..	..	..	..	..	..	..	1.0	10.0
Gram	0.8	6.8	1.0	4.4	..	..	..	..	..	..	..	..	..	..	..	..	1.8	11.2
Peas	0.8	14.3	0.8	11.1	1.5	22.3	1.5	35.0	2.0	47.7	1.5	20.7	1.5	25.8	1.5	32.9	11.0	208.6
Jowar (green fodder)	1.5	563.9	1.5	363.3	1.5	456.5	1.5	254.2	1.5	442.5	1.8	447.3	1.5	436.3	1.5	423.0	11.8	3386.8
Berseem (green fodder).	..	..	..	..	..	..	..	..	..	..	1.0	242.0	1.0	588.8	1.0	456.0	3.0	1288.8
Cotton	0.5	5.5	0.5	6.1	0.5	4.5	0.5	6.3	0.5	5.1	..	..	..	..	..	..	2.5	27.5
Dry fodder	6.8	153.1	7.0	263.4	6.8	209.3	6.8	343.8	7.5	293.9	7.5	271.9	7.5	267.4	7.5	286.6	57.0	2095.3
Summary																		
Cereals	5.3	85.0	5.3	182.3	5.3	121.1	5.3	201.6	5.5	160.7	5.8	154.2	6.0	153.4	6.0	166.9	44.3	1205.2
Pulses	1.8	21.1	2.0	21.1	1.8	25.5	1.8	36.1	2.0	47.7	1.5	20.7	1.5	25.8	1.5	32.9	13.8	230.8
Green fodder	1.5	563.9	1.5	363.3	1.5	456.5	1.5	254.2	1.5	442.5	2.3	689.3	2.5	1025.0	2.5	879.0	14.8	4673.5
Dry fodder	6.8	152.1	7.0	263.4	6.8	209.3	6.8	343.8	7.5	283.9	7.5	271.9	7.5	267.4	7.5	286.6	57.0	2098.3
Cash crop (cotton)	0.5	6.5	0.5	6.1	0.5	4.5	0.5	6.3	0.5	5.1	2.5	27.5

POTASSIUM FIXATION IN SOILS WITH SPECIAL REFERENCE TO INDIA

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(Received for publication on 16 February, 1951)

IF potash is added to the soil as a fertilizer, only upto 1/3 is usually recovered in crop under field conditions and more than half may remain in the soil in a form not believed to be readily available to plants [Nagelschmidt, 1944]. The effect is known as potassium fixation. As potassium broadly speaking, ranks amongst the 'Big Three' of plant nutrition (N, P, K), it is of great interest to know the mechanism of this fixation and the extent to which the potassium so fixed is really unavailable to the plants. It is of particular interest to know if this has anything to do with the relatively poor crop responses in India to potash. The fixed potassium was defined in earlier days as that portion of the total potassium in the soil, that was not considered to be readily available to plants. Amongst the earlier workers special mention may be made of Frear and Erb [1918], Page and Williams [1925], Chaminade [1936], Joffe and Kolodny [1937]. Different dilute acid extractants have been used like citric acid and buffered acetic acid, etc., and as there was uncertainty if the availability to plants could be precisely measured by these extractants, fixed potassium has now been defined as that portion of the non-exchangeable potassium, which cannot be removed by leaching with neutral salts. Amongst other salts NH_4Cl has been used for this purpose. So much work has accumulated in the subject that it will be useful to review critically at length, the important publications particularly with regards the causes for the differences in K-fixing capacities attributed to the clay minerals and the complications created by the interaction of the organic and inorganic types of fixation (A). It is also the purpose of this paper to evaluate the K-fixing capacities of the soil in different parts of India (B) and to assess the requirements of Indian soils for potassic fertilisers (C).

(A) *Mechanism of potassium fixation in soils and availability of the fixed potassium*

(1) *The earlier concept.* Gorbunav [1936] proposed that K is fixed by silica gels by an occlusion process depending on the electrokinetic conditions of the soil. Chaminade and Dronineau [1936] thought that the fixation is caused by the migration of the K from the surface of a colloid to the interior of the crystal which is coated by the colloid. But because soil colloids themselves are now generally considered crystalline as a result of X-ray and electron microscopic studies, these mechanisms fail to represent the phenomenon fully.

According to Gholston and Hoover [1948], chief among the soil minerals containing non-exchangeable K are the feldspars, muscovite, biotite and the hydrous micas (illite). These belong to the groups of layer and frame work silicates in which

K enters to compensate for the loss of positive charge resulting from the part replacement of Si^4 by Al^3 in the silicate tetrahedra. Volk [1934] held that potassium reacts with the so called 'silicates' to form difficultly soluble muscovite. A study of the structural relationship of micas and related substances by Pauling [1930], as also of glauconite and mica by Grunner [1935] showed that K of these micas should have been replaced to certain extent by other cations. There is evidence to show that such and similar replacements are possible. Barshed [1948] showed by experiments that by prolonged leaching with magnesium chloride, biotite $\text{K}(\text{Mg Fe})_3(\text{AlSi}_3\text{O}_{10})-\text{OH})_2$ could be converted into vermiculite, $(\text{MgFe})_3(\text{Si, Al})_4\text{O}_{10}(\text{OH})_2 \cdot 4\text{H}_2\text{O}$. The reverse change was also produced by him. Thus it appears that reactions are possible for the entry of K into fixed positions in certain minerals and its release in the long run by prolonged leaching with suitable reagents. Thus the conditions of fixation appear to be capable of being reversed. Volk [1938] however ascribes this fixation to several different processes and does not think that it is due to any single soil mineral.

(2) *Modern concepts.* The modern concepts at an understanding of the mechanisms of K-fixation started with Hoagland and Martin [1933] who pointed out that this fixation is accompanied by a reduction in the exchangeable capacity of the soil. This is confirmed by a number of later workers, namely Kolodny [1938], Truog and Jones [1938] although there was no exact quantitative relationship between the two according to Joffe and Levine [1938]. In 1947 Joffe and Levine showed that the amount of K fixed actually increased with the amount of K adsorbed into the exchangeable complex and that K from the fertilizer must first be absorbed before it can be fixed. This explains the role of cations already adsorbed into exchangeable position on this K-fixation, because the added K must compete with them for positions in the exchangeable complex before it can be fixed. Thus if Ca, Na, etc., are the ions already present, they can be replaced by K, while this replacement is not so easy if NH_4 or H be the cations already present. This has been confirmed by Wiklander [1950] using radio-active potassium as the tracer element. These experiments point out a series of equilibria for K.

Soluble K \rightleftharpoons exchangeable K \rightleftharpoons K fixed K, although the equilibrium between the exchangeable and fixed K is a relatively slower process and changes its direction with changes in the conditions of the experiment. Seatz and Winters [1944] studying the relationship between fixation, exchange capacity and the complementary ion suggested that the exchangeable K is in equilibrium with the K bearing soil minerals and that by fertilizing or cropping, K tends to be respectively fixed or released. Wood and De Turk [1941 and 1943] established that on some Illinois soils, heavy dressings of K produced fairly insoluble form which became exchangeable again as the soils were depleted of their exchangeable K.

The importance of mass action law on these equilibria can be seen from the fact that Attoe and Truog [1946] showed that the fixation of applied exchangeable K followed the empirical relation : $\log Y = K_1 \log X - C$, where Y = the amount out of the added K that is remaining in the exchangeable condition, X = the rate

of application of K, K_1 and C being constants determined by the extent of fixation. Ayres [1941] showed the importance of concentration of the K salts in the percolating solution for K-fixation. Martin *et al.* [1946] held that the importance of drying observed by many workers on the fixation processes was more in increasing the concentration of K salts in solution rather than to any dehydration process.

Organic and inorganic fixation of K. Hurwitz and Batchelor [1943] found micro-biological fixation of K in unleachable form of upto 200 lb. per acre on ad ling plant material to neutral silt loam. This type of fixation may be occurring during moist conditions of many soils manured with organic matter. The K-fixing bacteria can take up K from the added organic and inorganic matter and from the silicate materials. Aleksandrov [1949] reports that bacillus siliceus had the ability to decompose the alumina silicates and fix K in their body in the first instance and then render it available as they die and get their bodies decomposed. In agreement with the above view, Pchelkin [1946] found that the oxidation of the organic matter of chernozems with H_2O_2 reduced the amount of K-fixed.

Martin *et al.* [1946] working with arid soils where bacterial population do not thrive well showed that the fixation of potassium is due mostly to inorganic fixation. Organic matter was on the other hand found by Joffe and Levine [1947] to reduce the inorganic fixation. The simple explanation for this is that K salts of organic acids are weak and ionise less thereby reducing the effective concentration of the K ion in solution, which can be converted into the exchangeable and from there into the fixed condition. It may also be possible that this organic matter blocks the attraction spots in the mineral lattice responsible for K fixation as envisaged by Martin *et al.* [1946] or even prevent the shrinkage of the crystal lattice, which was found necessary for some types of inorganic fixation.

The Two types of inorganic fixation. There appear to be two distinct kinds of inorganic fixation, one brought about by drying, particularly alternate wetting and drying and the other taking place even in continuously moist conditions [Stanford, 1948]. Attoe [1947] showed that the moist fixation increased with pH and that it is fairly soluble in 0.5 N-HCl, while the fixation proceeding under dry conditions is independant of pH and fairly resistant to extraction with 0.5 N-HCl. Several workers have shown that the K-fixation is reduced by preventing the tendency of the soil to dry out and that greatest fixation occurs in those layers in the soil profile that are subject to alternate wetting and drying. This type of fixation is attributed by Truog and Jones [1938] to the strong attraction offered by adsorbed K which prevents a re-expansion of the crystal lattice and hence the re-entrance of water. Hendricks and Dyal [1950] and de Castro [1950] have shown that K fixation is accompanied by a loss of water of hydration and a reduction in surface area of the clay. Raney and Hoover [1947] recorded that 23 per cent of the 2160 p. p. m. of applied K was fixed during one month of moist storage in a montmorillonitic soil and 57 per cent became fixed on subsequent air-drying. The moist fixation was small on the other hand in the kaolinitic soil where the air-drying actually released a part of the fixed potassium. The moist fixation here might be due to the stimulation of microbial activity resulting in a decrease in fixation

due to subsequent drying when their bodies are decomposed as kaolinites are not known to take part in inorganic fixation. Stanford [1948] while agreeing with Truog and Jones' explanation considers that this type of inorganic fixation due to drying occurs with montmorillonitic type of clay minerals and is of a small value compared to the fixation occurring under humid conditions by exchange reactions with illite and other micaceous minerals. Hauser [1941], and Seatz and Winters [1947] have also shown that soils containing micaceous minerals possess the greatest K-fixing capacity. But Volk [1938] showed that powdered pure kaolinite fixed 440 p. p. m. of K, muscovites from 0—1700 and bentonite on the other hand the highest viz. 8850 p. p. m. These figures depend on the nature of the cations in the exchangeable complexes and in the fixed positions which explains differences in the order of fixation for the different clay-minerals obtained by different workers.

Specific nature of this fixation phenomenon and its mechanism. Joffe and Levine [1939] have shown that this fixation is peculiar to K as other cations like Na, Ca, Mg and Ba do not appear to be fixed in this way. Page and Bayer [1939] pointed out the importance of ionic size for this capacity. According to this view, ions of a size permitting them to fit closely into the cavities inside of the hexagonal net of oxygens are least replaceable. For example K with a diameter of 2.66 \AA closely fits with the cavity which has a diameter of 2.8 \AA and is tightly held. NH_4 which has near about the same size (2.86 \AA) should also exhibit this phenomenon, while smaller ions like Na, Ca, Mg with diameter of 1.96, 1.96 and 1.46 \AA should not have this capacity. The evidence for the fixation of NH_4 was provided by Chaminade [1940], Joffe and Levine [1947a] Stanford and Pierre [1946] and Wiklander [1950]. This also explains the reason why K cannot compete with NH_4 as easily as it does with Ca, Mg, Na, etc. But this explanation as pointed out by Wiklander [loc. cit.] is not complete as it does not explain why Ba with a diameter 2.62 \AA comparable with that of K does not show this fixation phenomenon in illites, while H with an infinitely small diameter (~ 0.0) shows it.

In Table I are given the ionic radius, ionic potential ($\frac{\text{valency}}{\text{radius}}$) on which depends the capacity of the cations to form hydrates and complexes taken from the publication of Emeleus and Anderson [1938] as well as the ratios of the radii of the cation R_c and the oxide anion ($R_a = 1.33 \text{ \AA}$ after Wycoff, 1931).

Table I shows how these cations K and Ba, are very much separated by their ionic potential, which when it is greater, greater is also the capacity for hydrate formation, etc., according to Emeleus and Anderson [loc. cit.]. The ability to enter fixed positions in 12 co-ordination in those Alumino-silicate lattices is determined by the competitive capacity of the Alumino-silicate oxygen structures to compete with the hydration complex for the cation. Thus if the cation has higher ionic potential and found highly hydrated in aqueous solution, the less will be the capacity of the Alumino-silicate oxygen structures to take away the cation from the hydration complex. From this point of view, it is clear how K and Ba are far separated

having ionic potentials equal to 0.71 and 1.4 with Ba requiring a stronger force to pull it from its water hull.

TABLE I

Ionic potential and formation of complex ions

Ion	Ionic radius	Rc/radius Ra ratio	Ionic potential
Cs	1.67A°	> 1.0	0.61
Rb	1.48	> 1.0	0.67
NH ₄	1.43	> 1.0	0.69
K	1.33	1.0	0.71
Na	0.98	1.0—0.73	1.0
Ba ²	1.31	1.0—0.73	1.4
Hg ²	1.12	1.0—0.73	1.8
Cd ²	1.03	1.0—0.73	1.9
Ca ²	0.98	1.0—0.73	2.0
Zn ²	0.83	< 0.73	2.4
Co ²	0.82	< 0.73	2.4
Ni ²	0.78	< 0.73	2.5
Fe ²	0.67	< 0.73	4.5
Co ³	0.66	< 0.73	4.5
Ni ³	0.65	< 0.73	4.6
Al ³	0.57	< 0.73	5.3
Pt ⁴	0.66	< 0.73	6.0
Be	0.39	< 0.73	5.9
H	∞ 0.0	∞ 0.00	Very high

The radius ratio determines the coordination number of the cations in ionic crystals [Stillwell, 1938], because the number of anions that can be accommodated tightly around the cation is obviously determined by their relative sizes. A cation can coordinate six anions when this ratio is between 0.41 to 0.73, and eight when the ratio is between 0.73 to 1.0. When this is 1.0 as in metallic structures 'the metallic bond' with the capacity to hold 12 partners arises under suitable circumstances. As there are 12 oxide anions, six from each of the two adjacent Alumina layers around the cation in micaceous structures, it is only that cation that can coordinate all the 12 and fit into the space between them, that would form a compact structure from which once formed it would be difficult to replace the cation by ordinary exchange reaction. The radius ratios for the cation and anion given in Table I, shows that K can form compact 12 coordinate structure, while Ba cannot.

Thus in addition to the usual mass action law, the conditions determining this fixation phenomenon appear to depend on (1) the above competitive capacity, (2) the coordination number of the cation with oxide atoms, (3) the size of the cation and

the fit it makes with the vacant space and (4) the number and positions of the oxygen atoms available for coordination from the two adjacent silica layers in the different clay minerals. It is, therefore, obvious that all these conditions are best satisfied in illite and other micaceous minerals in respect of K or NH_4 but not Ba. In the case of montmorillonite, it must also be the same if it has the structure given by Hoffman *et al.* [1933]. But as barium was also found by Page and Bayer [loc. cit.] to be highly fixed by this mineral, the bond attaching this cation must be stronger here than in the illites or micas so as to offer a force greater than that between Ba and its water hull, while the number of coordinated oxygen atoms must also be less than twelve which is not the case with Hoffman's structure. These would therefore appear to support the structure proposed by Edelman *et al.* [1940, 47] wherein the bonds are Si-OH type and not those simply blocked Al-tetrahedra. The conclusion regarding the strength of the bond is also borne out by the fact that the fixed K by drying of montmorillonite could not be extracted with 5N HCl while that of micas occurring under wet conditions could be extracted by Attoe [loc. cit.]. The position of K here should resemble that in feldspars more than that in micas. While determining relative or specific cations fixing capacity for Ba, Rb, Cs and NH_4 , one should use as leaching solution neutral salts with cations of low fixing capacity in order to avoid erroneous conclusions. The use of NH_4 salts by Joffe and Levine [1939] with NH_4 itself having high fixing capacity marked the fixation of Ba in montmorillonite, while Page and Bayer [1939] using acid could easily show fixation of Ba.

As regards the fixing capacity of H-ion, there are two views. One attributes the H-ion effects to the presence of polyvalent Al^3 or Fe^3 which it produced by destruction of some of the complexes in the very processes of introducing the H-ion into the complex. The other view attributes direct effects to the H-ion. Because of the exceedingly small size of the H-ion, it is possible for it to go straight to the centre where there is a deficit of positive valency and remain close to the Al^3 ion after it has substituted Si^4 in some of the tetrahedra in the layer and frame work silicates. This will then be as near and compact as possible compared to the unsubstituted tetrahedra. Thus it is easy to picture how difficult it will be for other cations which are much bigger in size compared to the H, to replace this H so entangled by exchange reactions. That is how if H or NH_4 ions which can themselves go into the fixed condition are present in the exchangeable, it will be difficult for even K to compete with them while it is easy compete and replace Na, Ca, Mg and Ba, etc. Thus the effect of liming on K fixation and to release reported by a number of workers is produced by replacing the tough H by Ca in the exchangeable position and the subsequent replacement of Ca by K resulting in an alteration in the fixed potassium.

Availability to plants of this fixed potassium. Wash and Cullinan [1945] showed that fixation by alternate wetting and drying was not permanent. It was however large enough to cause severe K deficiency symptoms in a first crop of mustard in pots while the growth of a second crop indicated a release of K from the fixed state.

De Turk *et al.* [1943] report that under some conditions depending on the soil type, potassium may be fixed in a non-exchangeable form to a limited extent, which however is recoverable in the course of a few weeks and completely after a long time. Ayres *et al.* [1947] noted that in Hawaiian soils under napier grass, a release of 3400—4200 lb. K_2O per acre in $4\frac{1}{2}$ years from non-exchangeable sources could be obtained with little corresponding decrease in the level of exchangeable K. Attoe [1948] reports that oats recover almost all such non-exchangeable fixed K from the added fertilizers. This seems to be the opinion of many other workers although Kolodny and Robbins [1940] report that this is only slightly available to plants. Hoover, Jones and Gholston [1948] have shown that this non-exchangeable K is more readily available from soils which are more weathered or contain 2 : 1 clay mineral types or limed to pH 6.6 to 7.2 compared to others less weathered or containing 1:1 clay mineral types or pH 5.7 to 6.6. This means that as is to be expected, the K of the secondary minerals is more readily available than the K of the primary minerals; and as the primary minerals are not ordinarily expected to be present in the clay fraction, fixation takes place more in the clay than in any other mechanical fractions. The potassium of the framework silicates like the feldspars is relatively less available. Sen Deb and Bose [1949] have shown that part of both the citric acid soluble K and that actually absorbed by the rice crop from the red and lateritic soils of India came from the non-exchangeable and is determined by the nature of the fertilisers or manure added.

(B) *Potassium fixation in Indian soils*

Viswanath [1925] studied the availability of soil K as influenced by liming. Nandy [1946] reports that it is only at pH 6.0 to 7.0 that K-fixation or its release occurs while liming acid soils of Bengal. Pathak, Mukherjee and Srikhande [1950] reported studies on the amount of K fixed in the manured and unmanured soils at different depths and in different mechanical fractions both before and after the destruction of organic matter. They confirm the view that micaceous soils have a high K-fixing capacity and that organic matter reduced this amount. As they find high values for silt also, it may perhaps be presumed that primary micas are taking part in this. They make the interesting observation that the unmanured wheat soil had the maximum K-fixing capacity in the surface only while the manured soil had it in the 2nd ft. layer. It will be of interest if this is confirmed in a large number of manured and unmanured wheat soils. More experimental work on Indian soils is desirable.

Ukil and Desai [1944] compiled a map of India showing the distribution of total K_2O district-wise. From it, it is seen that the districts particularly of the Bombay and Madras states derived from the Deccan trap and crystalline gneiss tended to have lower values for total K_2O . Out of 137 districts for which data were compiled, 17 districts namely Darjeeling, Jalpaiguri, Rajshahi, 24-Paraganas, Jessore, Palamau, Angul, Lucknow, Banda Parbhani, Nizamabad, Medak, Atrafi Balda, Raichur, Warangal, Karimnagar and Kashmir-North had values of total K_2O greater than 1.6 per cent on the soil, while 26 districts, namely Chittor, Chingelapat, South Arcot, Salem, Madura, Tanjore, Ramnad, South Kanara, Malabar,

Broach, Surat, Sholapur, Bijapur, Balaghat, Darrang, Sylhet, Balassore, Jalaun, Hamirpur, Coorg, Bangalore, Rewa-Umrai, Baroda, Navasuri, Amreli and Mehsena had values less than 0.3 per cent.

The percentage of the total potash that is in the available form as determined by the chemical methods when calculated from the collections of Ukil and Desai [loc. cit.] reveal interesting results. The vast majority had values of 1 to 10 per cent of their total K_2O in the 'available form'. The districts of Chingelpat, North Arcot, Tanjore, Anantapur in the Madras Presidency, Sholapur and Bijapur in the Bombay Presidency, Hooghly from Bengal, Coorg, Baroda and Amreli from the States had over 10 per cent of their total K_2O in the available form and had therefore relatively less potassium fixing capacity. On the other hand, the districts of Jalpaiguri (Bengal), Singhbhum, (Bihar), Lucknow, Banda, Pratapghar and Gorakhpur (Uttar Pradesh), Atrahi-Balda and Karimnagar (Hyderabad State) had the lower percentage under 1.0 per cent only of their total K_2O in the available form. A proper appraisal of the contributing soil conditions in these two sets of districts would reveal the natural conditions that have either gone to fix soil-K or those that favoured its release in the available form.

In Table II are given the probable geological origin, the nature of soils, the order of soil pH, the total and available K_2O and the percentage availability. Column 2 is compiled from the book of Wadia [1939] and the *All India Soil Survey Scheme Report* [1945], Column 3 from the Map of Viswanath and Ukil [1943] and the *All India Soil Survey Scheme Report* (1945) and the percentage availability was calculated from the data compiled by Ukil and Desai [1944] as

$$\frac{\text{available } K_2O}{\text{total } K_2O} \times 100.$$

From Table II, it is seen that those districts that have very high per cent availability of the soil K greater than 11.0 per cent (Nos. 1 to 6, Group I) have high available potash greater than 0.04 per cent, although their total K_2O is less than 0.7 per cent of the soil; and those districts with lowest availabilities less than 1.0 per cent of their total K_2O (Nos. 10 to 17, Group II) have indeed lower available K_2O less than 0.025 per cent in spite of their total K_2O being above 0.75 per cent reaching in some cases as high as 4.0 per cent. There are also soils (Nos. 7 to 9, Group I-A) of moderately high availability between 10 to 11 per cent, in which, this is not attributable so much to higher available K_2O as to the lower amounts of total K_2O between 0.20 to 0.25 per cent. There is then the third group not given in this table of the vast majority (120 districts), having availabilities between 1 to 10 per cent of their totals.

This table also shows that this great difference in the availabilities in the soils of Table II cannot be attributed to the colour or climatic zone of the soils or even to the pH-range of the places. The geological origin of the soil taken, however, with the other factors seems to reveal the essential difference in the soil conditions likely to contribute to these great differences in K availabilities.

TABLE II

Relation between K-availability and the geological and other properties of the soils

District	Probable geological origin of soils	Nature of soils	pH range	Total K ₂ O average per cent	Available K ₂ O average per cent	Available K ₂ O × 100 Total per cent
<i>Group I.</i>						
1. North Arcot	Crystalline gneiss and some upper Gondwana	Just humid red ferruginous or even yellow loams and sands with some deep black soils along rivers	Very alkaline and also some moderately alkaline	0.50	0.32	54.1
2. Anantapur	Crystalline gneiss surrounded by Dharwarian system	Semi-arid red loams in the south and some medium black soils on the north	....	0.37	0.065	17.6
3. Bijapur	Deccan trap and border of crystalline gneiss	Semi-arid medium black soils with some red and deep black soils	Very alkaline	0.35	0.102	29.1
4. Sholapur	Deccan trap	Semi-arid medium black and some reddish and coarse grey soils	....	0.25	0.057	34.8
5. Baroda	Recent, some trap, gneiss, Dharwarian and lower Cretaceous	Semi-arid black silty and sandy loams	....	0.25	0.046	17.6
6. Hoogly	Recent alluvium	Per-humid highly weathered and leached heavy clay and loam soils in 'bheel' or anuro-bic conditions adjacent to red soils	....	0.63	0.103	16.4
<i>Group I-A :</i>						
7. Coorg	Crystalline gneiss and mica schists. Border of coastal alluvium	Humid dark reddish brown clay, red loam and lateritic soils	Neutral to just acidic	0.24	0.025	10.42
8. Chingleput	Recent and older coastal alluvium with upper Gondwana and some crystalline gneiss	Humid coastal sandy alluvium with red soils in the north and black in the south and some laterites	Neutral to just acidic	0.20	0.020	10.0

TABLE II—*contd.*
Relation between K-availability and the geological and other properties of the soils—contd.

District	Probable geological origin of soils	Name of soils	pH range	Total per cent of K ₂ O averages	Availability per cent of K ₂ O average	Availability × 100 Total K ₂ O per cent
9. Tanjore	Recent and older coastal alluvium with some crystalline and calcareous deposits on the border	Humid coastal sandy alluvial soils with some medium black and red loams on borders	Moderately alkaline and also neutral to just acidic	0.22	0.023	
<i>Group II.</i>						
10. Antrāṭ-Bādā	Crystalline rocks and on one side upper Vindhyan	Semi-arid red loams with some laterites and some deep black soils along border	....	4.41	0.023	0.52
11. Karīnnagar	do. plus Cuddapah	Semi-arid red loam with some deep black soils along the river	....	0.82	0.019	0.67
12. Singhbhum	Dharwarian and some crystalline	Humid red and some black soils also, with relatively higher CaO and Al ₂ O ₃ in HCl extracts than Fe ₂ O ₃	Acid soils	0.86	0.009	0.94
13. Jalpaiguri	Recent alluvium	Per-humid Brahmaputra alluvial sandy soils, borders of Brown sandy hill soils	....	1.2	0.008	0.97
14. Gorakhpur	Ganggetic alluvium	Humid Ganggetic alluvium containing some calcareous and Faral soils	Neutral to just acidic and even moderately alkaline	0.81	0.008	0.99
15. Pratāpghar	do.	Just humid ganggetic alluvium (usar) soils	Neutral to just acidic	0.79	0.005	0.80
16. Banda	do., borders of upper Vindhyan	do. with some red and black soils	Moderately alkaline	1.19	0.011	0.9
17. Lucknow	Ganggetic alluvium	Just humid alluvial soils and Usar soils (mixed sodium and calcium soils)	Highly alkaline	1.0	0.008	0.008

Out of eight districts in the low availability group (Nos. 10 to 17), five have their origin in the Gangetic alluvium and out of these five, three contain *usar* or alkaline soils whereas there is only one out of nine in the high availability group and that too characterised by the presence of 'bheel' or anerobic and semi-peaty conditions. It seems, therefore, that the soils of the Gangetic alluvium generally and more particularly when they contain sodium clay or *usar* soils, tend to have low potash availabilities (i.e.) greater K-fixing capacities except when the soils are in the 'bheel' and semi-peaty conditions which bestowed on them higher availability. The higher total K_2O in this region and their possible original source being the crystalline core of the Himalayas which are rich in biotite-micas, the greater K-fixation in this region may be attributed to the micaceous minerals of this region.

The group of high availability is characterized by soils of the crystalline gneiss or their coastal alluvium when those districts have their borders of cretaceous origin or from upper Gondwana or the Dharwarian. But when the borders are of the Vindhyan (Group II), or Cuddapah systems, or even when the district is more or less entirely Dharwarian, as in Singhbhum, the soils had low potash availabilities. This brings into prominence the borders by virtue of the minerals they contribute to the weathered soil. For the districts for which no K-availability data are known, this gives an indication to expect low availability when the borders are of the Vindhyan and Cuddapah systems and high availability when they are cretaceous or Gondwana deposits. As the last mentioned systems are known to contain the coal of India, and as high availability is obtained in those as well as the Gangetic alluvium which is under semi-peaty conditions, the reason for their high availability or low fixation may, perhaps, lie in the action of their organic debris. There are some places in the Deccan trap, showing high potash availabilities.

(C) *Requirements of Indian soils for potassic fertilisers*

Under the tropical climatic conditions obtained in India, the soils are subjected to more intense weathering than under temperate conditions resulting in the liberation of adequate quantities of potash which forms a substantial part of soil mineral matter. Most of the soils in India except the laterities and the acid soils, are thus found to be well provided with potash reserves. Due to this, manurial trials with K fertilizers either alone or in combination with N and P have generally failed to give significant response, except in the case of particular crops like tobacco, chillies, tea, potato and particular soils like the laterities in South India and the acid soils from which potash and other minerals have been leached out. The common cereal crops are consequently not likely to respond to dressings of K until the K reserves of soils are exhausted. The problem may arise in the long run as a result of intensive cropping and fertilizing with N and P fertilizers. Even then the natural processes of weathering in India have to be reckoned as these may keep pace with the removal of K by crops. It must also be considered that in any judicious manurial programme on schedule, application of organic manures forms an important part along with the use of N and P fertilizers—particularly in India where the cultivator has available this traditional manure. Such manures will add to the soil sufficient

quantities of K also for crop requirement so that the need for further additions of K in the form of fertilizers may not arise.

In order to ascertain the need for K fertilizers under N-P fertilizer practice in India, it would be first of all necessary to carry out long term experiments to study the equilibrium of K reserves obtained by cropping, weathering and fertilizing with N-P fertilizer. The role of addition of organic manures in the maintenance of K reserves has also to be studied.

The importance of K fixation in Nature lies in the fact that it not only regulates the supply of soil K for the plants and protects it from the leaching action of rain, but also regulates the available Ca/K balance in the soil. Lamb [1935] showed that wide ratio for this leads to serious disturbances in plants as was also evident from the experiments of Ramamoorthy and Desai [1946]. The theoretical significance of this fixation phenomenon seems to be in opposing the normal weathering sequence of minerals as discussed by Nagelschmidt [loc. cit.].

SUMMARY

Three types of potassium fixation, (1) the organic, (2) the inorganic occurring under conditions of alternate wetting and drying and (3) the inorganic fixation occurring under continuously wet conditions are recognized. The mechanism of the two types of inorganic fixation and the minerals involved are discussed. The specificity of this fixation process was elucidated by an application of Goldschmidt's laws of crystal chemistry. According to this, those ions that can form 12-co-ordination with oxygen in micas and even less in montmorillonite and those of small ionic potential with which the aluminosilicates can form stronger complexes than the water of hydration are the ones involved in this specific fixation phenomenon. Conversely information could be got from a knowledge of the fixation specificity to Cations, about the strength of this fixation bond compared to that between the cation and its water hull and the number of oxygens available for co-ordination. This brought out evidence for the strong Si-OH bonds in montmorillonite.

The potash availabilities in the Indian soils are related to their geological origin. Gangetic alluvium and those soils bordering the Vindhyan system have generally low K-availability or high fixation capacity while soils of the crystalline gneiss or coastal alluvium bordering cretaceous or the Gondwana systems had high availability or low K-fixation capacity.

REFERENCES

- Aleksandrov, V. G. (1949). *Dokl. Akad. S. Kh. Nauk* No. 12, (12-19)
Attoe, O. J. (1949). *Proc. Soil Sci. Soc. Amer.* **13**, 112
Attoe, O. J. (1947). *Ibid.* **11**, 145
— and Truog, E. (1946). *Ibid.* **10**, 81
Ayres, A. S. (1941). *Soil Sci.* **51**, 265
—, Takahashi and Kanehiro, (1947). *Proc. Soil Sci. Soc. Amer.* **11**, 175

- Barshed (1948). *Amer. Miner.* **33**, 655
- Chaminade and Dronineau (1936). *Ann. Agron.* No. 6, 818
- Chaminade (1940). *Compt. Rend. Acad. Sci.* **210**, 264
- De Turk E. E. *et al.* (1943). *Soil Sci.* **55**, 1
- De Castro, A. H. (1950). *Trans. 4th Int. Cong. Soil Sci.*, **2**, 73
- Emeleues and Anderson (1938). *Modern Aspects of Inorganic Chemistry* Van Nostrand N. Y. 166
- Edelman, C. H. and Favejae (1940). *Z. Krist (A)* **102**, 417-431
- Edelman, C. H. (1947). *Verre et silicates Ind.* **12 Supp.** 3-4
- Frear and Erb L. E. (1918). *J. agric. Res.* **15**, 59-81
- Gholston and Hoover, C. D. (1949). *Proc. Soil Sci. Soc. Amer.* **13**, 116
- Gorbunov, N. I. (1936). Quoted by Joffe and Levine (1939)
- Grunner (1935). *Amer. Miner.* **29**, 699
- Hauser, G. F. (1941). Quoted by Pathak *et al.* (1950)
- Hendricks S. B. and Dyal R. S. (1950). *Trans. 4th Int. Congr. Soil Sci.* **2**, 71
- Hofmann, K. ; Endell and Wilm. (1933). *Z. Krishalogr.* **86**, 340
- Hogland and Martin (1933). *Soil Sci.* **36**, 1
- Hoover, C. D. ; Jones, U. S. and Gholston, L. E. (1948). *Proc. Soil Sci. Soc. Amer.* **13**, 347
- Hurwitz, C. and Batchelor, R. W. (1943). *Soil Sci.* **56**, 371
- Joffe, J. S. and Kolodny, L. (1937). *Proc. Soil Sci. Soc. Amer.* **1**, 187
- Joffe, J. S. and Levine, A. K. (1939). *Ibid.* **4**, 157
- (1947, a), *Soil Sci.* **63**, 151
- (1947). *Soil Sci.* **63**, 241, 329
- Kolodny, L. (1938). Quoted by Joffe and Levine (1939)
- and Robbins, W. R. (1940). *Soil Sci.* **49**, 303
- Lamb, J. (1935). *Soil Sci.* **40**, 365
- Nagelschmidt, G. (1944). *Imp. Bur. Soil Sci. Tech. Comm.* No. 42
- Nandy, N. K. (1946). *Indian J. Agric. Sci.* **16**, 435
- Martin, J. C. *et al.* (1946). *Proc. Soil Sci. Soc. Amer.* **10**, 94
- Page, J. B. and Baver, L. D. (1939). *Ibid.* **4**, 150
- Pathak, A. S. : Mukherjee, S. K. and Srikanth, J. G. (1950). *Curr. Sci.* **19**, 120
- Pauling (1930). *Nat. Acad. Sci. Proc.* **16**, 123
- Phaelkin, V. U. (1946). *Pedology*, 604-610
- Ramamoorthy, B. and Desai, S. V. (1946). *Indian J. Agric. Sci.* **16**, 103
- Raney, W. A. and Hoover, C. D. (1947). *Proc. Soil Sci. Soc. Amer.* **11**, 231
- Seatz, L. F. and Winters, E. (1944). *Proc. Soil Sci. Soc. Amer.* **8**, 150
- Sen, A. T. ; Deb, B. C. and Bose, S. K. (1949). *Soil Sci.* **68**, 291
- Standford, G. (1948). *Ibid.* **12**, 167
- Standford and Pierr (1946). *Ibid.* **11**, 155
- Stillwell, (1938). *Crystall Chemistry*, McGraw Hill Book Co., New York
- Truog, E. and Jones, R. L. (1938). *Ind. Eng. Chem.* **30**, 882
- Ukil, A. C. and Desai, S. V. (1944). *Map of Potash Distribution in India*, I. A. R. I.

- Viswanath, B. (1925). *Madras, Agric. Chem. Annu. Report*, 228
—— (1943). *Soil Map of India*, I. A. R. I.
Volk, G. W. (1934). *Soil Sci.* **37**, 265
Volk, G. W. (1938). *Soil Sci.* **45**, 263
Wadia, D. N. (1939). *Geology of India*, London
Walsh, T. and Cullinan, S. J. (1945). *Emp. J. Expt. Agri.* **13**, 203
Wiklander (1950). *Soil Sci.* **69**, 261
Wood, L. K. and De Turk, E. E. (1941). *Proc. Soil Sci. Soc. Amer.* **5**, 152
—— (1943). *Ibid.* **7**, 148
Wyckoff, R. W. G. (1931). *The Structure of Crystals*. Reinhold Publish, Crop, New York

OCCURRENCE OF SODIUM CHLORIDE IN INDIAN SOILS

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(Received for publication on 26 March, 1951)

(With two text-figures)

SODIUM chloride occurs practically in all soils. Saline and alkaline soils may contain a good deal of it in addition to other sodium salts. There are localities where the salt concentration is so high that it is possible to manufacture common salt from them. The salt in such localities is geologic in origin. Concentration of salt in such localities is not due to normal causes of accumulation of salt in the soils but due to earth movements in the past geologic ages [Gee, 1934].

In soils with normal geology, salts get into the soil in various ways. Decomposition of the soil rock material with water followed by subsequent chemical reactions gives rise to salts in soil. The other salts in the soil solution may be used by the growing vegetation, leaving a chance of slow accumulation of sodium chloride which is not used up in large quantities like other salts. Sodium chloride gets into the soil from outside sources too. Wind carries salt from the sea and deposits the material on to the land [Blanford 1876; Buck and Wright 1897; La Touche 1909; Sen 1943, 1945]. Irrigation water adds various salts into the soil [Scofield, 1940]. Sea water flooding may make soils alkaline [Scofield and Headley, 1921], introducing considerable quantities of sodium chloride into them. Rainfall has been observed to be adding about 35 lb. of NaCl per acre annually [Passerini, 1894; Kinch, 1900; Jorissen, 1906; Crowther and Stewart, 1912; Knox, 1915; Artis, 1916 and Hansen, 1931].

Functions of sodium chloride in plant nutrition are very little known. A 20-year experiment at Rothamstead conducted by Lawes puts to doubt the use of NaCl in increasing the yield of wheat. On the other hand, it is known that salt is used to check rank growth of crops [Storer, 1897]. Application of sodium chloride to soils is, however, expected to release lime, potash and magnesium in them by base exchange and other reactions.

On the other hand, there is some evidence, from the studies of Sengupta *et al* [1946] that soils rich in NaCl are devoid of nitrates while those containing sulphates contain appreciable quantities of them. The exact nature of the effect of NaCl on nitrification in soils is not known. But the absence of nitrates in a large number of soils rich in NaCl is too prominent to be ignored.

NaCl is thus known to have rather harmful effects on soil properties affecting plant growth. The study of sodium chloride in soils is, therefore, important. An attempt has been made in the present paper to deal with the amounts of sodium chloride in different Indian soils, their relationship, if any, with the distance from the sea which is a vast reservoir of saline water and the comparative study of the amounts of sodium chloride in virgin and cultivated soils.

MATERIAL AND METHODS

Soils. 43 virgin soil profiles (up to five ft. depth) collected from different parts of India were used during the present investigation. Fifty two cultivated soils (surface 1 ft. and subsoil 1 ft.) were used to study distribution of NaCl in cultivated soils.

Method of estimation of sodium chloride. Water soluble salts were extracted from the soils (1 : 5) and the acids and bases were estimated by the usual methods of analysis [A. O. A. C., 1935]. They were then combined to form salts by the method of Leather [1905].

Distances of soil localities from the nearest sea board. The distances have been calculated from the Soil Map of India [Viswanath and Ukil, 1943].

Average annual rainfall. Figures of average annual rainfall for different soil localities have been compiled from *Annual Weather Review, Pt. A* [1938].

RESULTS

The results are detailed in Tables I, II, and III.

Table I gives the amounts of NaCl in different soils in grammes per 100 gm. of soil up to a depth of 5 ft.

In Table II are given the amounts of NaCl in different soils as averaged over the whole depth of the soil profiles, the distances of the soil localities from the nearest sea board in miles and average annual rainfall in inches.

In Table III are given the amounts of NaCl in cultivated and virgin soils.

TABLE I
Sodium chloride content of Indian soils (gm. per cent)

Soil locality	Depth in ft.				
	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.
Peshwar	·0351	·0369	..	..	·0088
Haripur Hazara	·0063	·0111	·0108	·0230	·0172
Mianwali	·0244	·0146	·0102	·0088	·0117
Gurdaspur	·0136	·0293	·0039	·0153	·0228
Lahore	·0073	·0361	·0761	·0673	·0219
Lyallpur	·0060	·0036	..	..	..
Kangra	·0015	·0148	..	·0158	·0261
Makrera	·0198	·0347	·0947	·1974	·1733
Tabiji	·0160	·0464	·0658	·0600	·0249
Padrauna	·0270	·0049	·0545	·0159	·0158
Sahjahanpur	·0021	..	..	·0042	·0044
Delhi	·0088	·0073	·0073	·0073	·0044
Ranchi	·0523	..	·0283	·0140	·0255
Pusa	·0039	·0046	·0041	..	·0048
Rangpur	·0070	·0100	·0006	·0062	..
Chinsurah	·0077	·0126	·0159	·0072	·0097
Dacca	·0036	·0073	·0073	·0073	·0044

TABLE I—*contd.*

Sodium chloride content of Indian soils (gm. per cent)

Soil locality	Depth in ft.				
	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.
Taliparamba	·0140	·0134	·0113	·0169	·0154
Koilpatti	·0234	·0746	·2516	·3452	·3335
Hagari	·0380	·1551	·2312	·2136	·2077
Samalkot	·0293	·0497	·0439	..	..
Coimbatore	·0034	·0050	·0086	·0106	..
Nandyal	·0088	·0117	·0629	·0586	·0585
Anakapalle	·0139	·0110	·0101	·0123	·0210
Jorhat	..	·0110	·0173	·0107	·0138
Sylhet	·0058	·0125	·0215	·0365	·0119
Karimgunj	·0153	·0178	·0333	·0269	·0257
Berhampur	·0100	·0146	·0132	·0132	·0161
Padegaon	·0117	·0205	·0293	·0454	·0585
Sirsi	·0039	·0055	·0041	·0051	·0041
Surat	..	·0066	·0010	·0062	·0095
Karachi	·0872	·1143	·0995	·1097	·1144
Sakrand	·0154	·0070	·0240	·2092	·1182
Nagpur	·0146	·0088	·0117	·0088	·0102
Mirpurkhas	..	·0041	·0203	·0222	·0413
Akola	·0059	·0059	·0088	·0059	·0117
Labhandi	·0039	·0044	·0020	·0073	·0044
Waraseoni	·0124	·0073	·0102	·0102	·0102
Powerkhara	·0034	·0009	·0030	·0033	·0021
Indore	·0088	·0038	·0066	·0122	·0073
Chandkhuri	·0073	·0073	·0102	·0073	·0072
Kheri	..	·0053	..	..	..
Kharua	·0218	·0126	·0203	·0103	·0012

TABLE II

Average salt content of soils, the approximate distance of the soil localities to the nearest sea board, and annual rainfall

Locality	Salt content (mg. per cent)	Distance from sea (miles)	Annual rainfall (inches)
Peshwar	16	704	14
Haripur Hazara	18	736	20
Lahore	63	672	20
Gurdaspur	17	744	30
Kangra	12	800	75
Lyallpur	8	560	13
Mianwali	14	624	13
Sakrand	75	144	7
Karachi	105	24	8
Mirpurkhas	18	160	7
Sahjahanpur	2	640	37
Padrauna	24	464	53
Ranchi	24	192	58
Nagpur	11	352	50
Akola	7	320	32
Waraseoni	10	360	54
Labhandi	4	240	52
Chandkhuri	8	272	54
Kheri	1	400	56
Powerkhera	2	384	50
Indore	8	240	34
Kharua	13	234	32
Makrera	104	208	20
Tabiji	43	288	21
Karimgunj	24	352	93
Sylhet	18	192	113

TABLE II—*contd.*

Average salt content of soils, the approximate distance of the soil localities to the nearest sea board, and annual rainfall

Locality	Salt content (mg. per cent)	Distance from sea (miles)	Annual rainfall (inches)
Jorhat	11	200	97
Dacca	6	144	87
Rangpur	5	312	83
Chinsurah	11	104	61
Sirsi	4	72	122
Padegaon	33	80	26
Surat	4	24	42
Coimbatore	7	104	23
Taliparamba	14	24	125
Koilpatti	206	88	34
Hagari	160	157	21
Nandyal	40	84	26
Samalkot	25	16	40
Anakapalle	14	24	38
Berhampur	14	24	46
Pusa	4	376	47
Delhi	7	480	27

TABLE III

Salt content of virgin and cultivated soils (average of 2 ft.) (gm. per cent)

Soil locality	Virgin	Cultivated
Karachi	·1007	·1891
Sakrand	·0112	·0471
Mirpurkhas	·0022	·0315
Makrera	·0273	·0060
Tabiji	·0312	·0087
Lyallpur	·0048	·0104
Gurdaspur	·0215	·0181
Kangra	·0081	·0017
Mianwali	·0195	·0147
Lahore	·0217	·0319
Berhampur	·0123	·0395
Haripur Hazara	·0087	·0209
Tarnab	·0360	·0570
Chinsurah	·0097	·0055
Rangpur	·0085	·0130
Ranchi	·0262	·0134
Padegaon	·0161	·0102
Surat	·0033	·0019
Padrauna	·0157	·0137
Sahjahanpur	·0011	·0134
Jorhat	·0055	·0113
Karimgunj	·0166	·0475
Sylhet	·0092	·0168
Labhandi	·0042	·0147
Akola	·0059	·0187

TABLE III—*contd.**Salt content of virgin and cultivated soils (average of 2 ft.) (gm. per cent)*

Soil locality	Virgin	Cultivated
Waraseoni	-0099	-0102
Nagpur	-0117	-0189
Powerkhara	-0022	-0172
Indore	-0063	-0222
Kharua	-0172	-0190
Kheri	-0026	-0153
Chandkhuri	-0073	-0124
Taliparamba	-0137	-0149
Koilpatti	-0490	-0271
Coimbatore	-0042	-0150
Hagari	-0966	-0248
Samalkot	-0395	-0174
Anakapalle	-0125	-0039

DISCUSSION OF RESULTS

Though the original source of NaCl must have been the rock materials from the decomposition of which salts generated and even now may be the major source of salt in places far off from the sea, a great portion of it may be forth-coming from the sea directly or indirectly. The origin of the salt of the Rajputana deserts has now been traced to be due to salt carried by the wind from the run of Cutch. Water in tube wells sunk in the vicinity of Calcutta had been reported to be developing salinity till they were full of salt and rendered unfit for human consumption. We may thus expect some relationship between the salt content of the soil and its distance nearest to the sea. From a study of the ground waters in Scotland, Barr [1914], who studied the influence of the ocean blown spray on the chlorine content of the inland ground waters, concluded that the ocean had an influence on the salinity of inland waters which was not limited to the waters near the sea board only but varied in intensity with the distance from the sea board. Jackson [1918] observed that chlorine contents of natural waters diminished in amounts as the distance from the ocean increased.

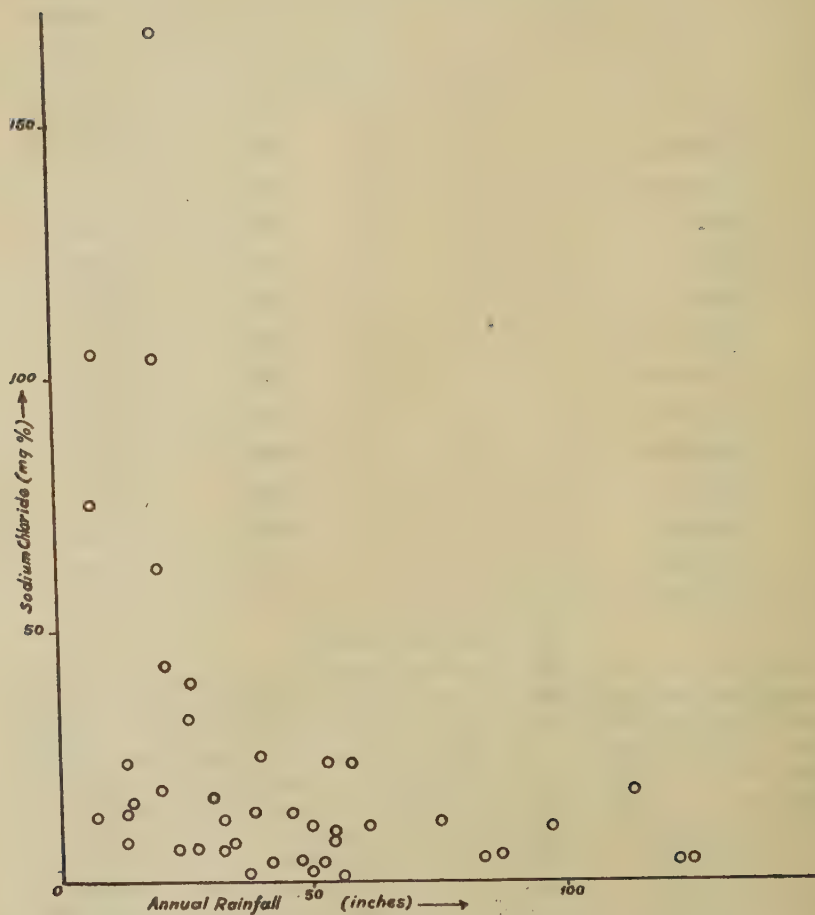


FIG. 1. Influence of rainfall on the salt content of the soil localities

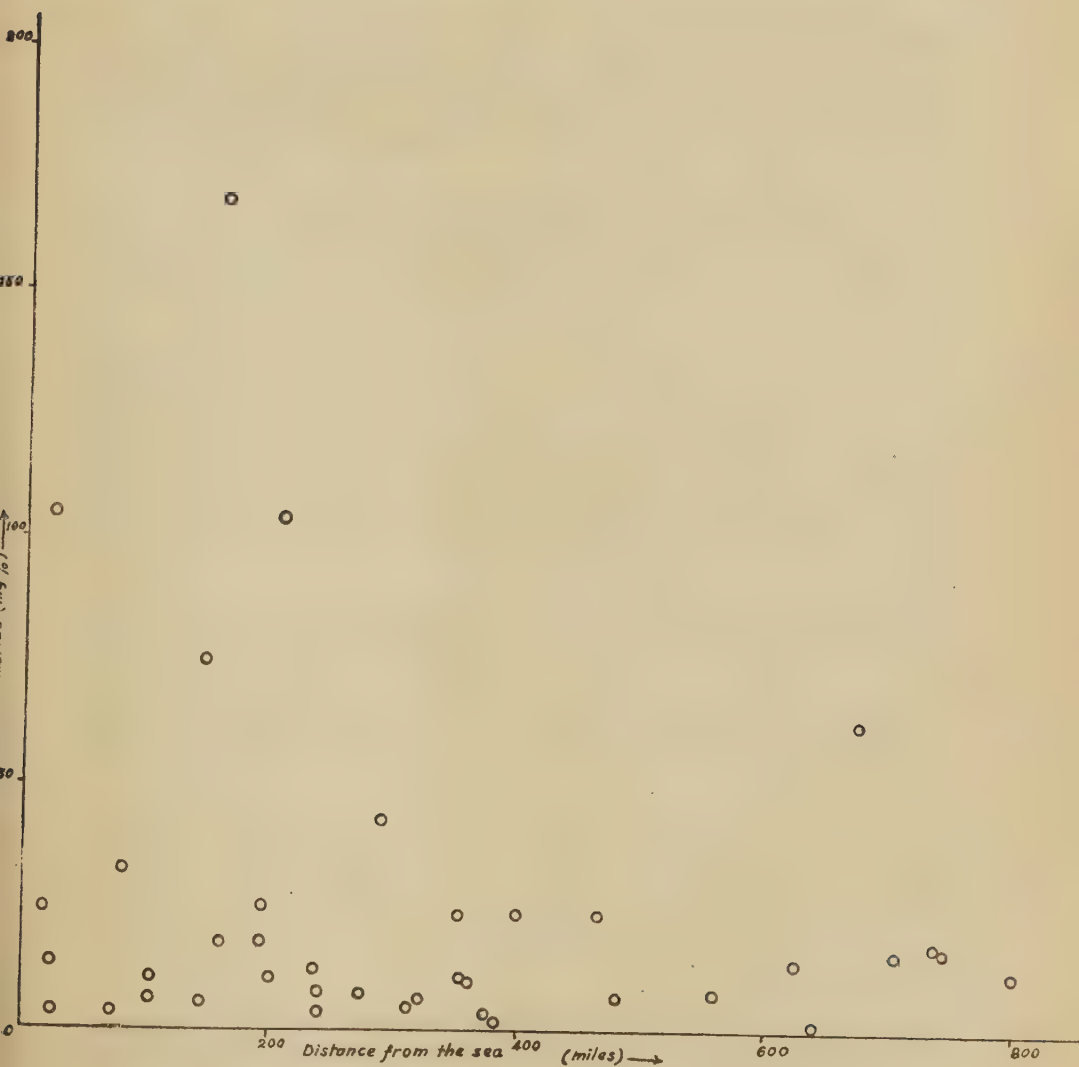


FIG. 2.—Salt content of soil localities and their distances from the nearest sea board.

Such relationship, in the case of soil extracts of Indian soils, however, is ill defined as can be seen from the scatter diagram (Fig. 2). But that a tendency of salinity to decrease with the increase of the distance from the sea definitely exists, is too prominent to be ignored. The wide scattering of the salinity specially in the vicinity of small distances from the sea may be due to the interference of high rainfall in these regions which always tends to lower down the general salt content of the soils.

The influence of rainfall on the salt content of the soil localities is illustrated in Fig. 1. There is a general tendency of the salinity to decrease with increase of rainfall. It appears, therefore, that though soil localities in the vicinity of the sea are all normally expected to have high salt contents, they are low in salinity if the rainfall is high and have high salinities if the annual rainfall of such places is low.

NaCl contents of the virgin and cultivated soils show that in quite a large number of cases the virgin soils contain higher amounts of salt than the cultivated soils. In a majority of cases, however, the cultivated soils contain more NaCl than the uncultivated ones. Though it appears that the latter is due to unfavourable salt balance [Scofield, 1940] or preferential absorption of salts other than sodium chloride by crops, the presence of larger amounts of salt in virgin soils renders any explanation difficult. For the present, it is probably fair to conclude that crop growth does not appear to affect the salt content of the soil.

SUMMARY AND CONCLUSIONS

Contents of common salt of a large number of Indian soils, both virgin and cultivated, are given. These were not saline or alkaline but agriculturally normal soils.

It has been observed that the NaCl contents of soils decrease as the annual rainfall of the soil localities and their distances from the nearest sea board increase.

There is some evidence that crop growth does not affect the NaCl content of a soil.

ACKNOWLEDGMENT

Some of the data of the salt content of the virgin soils, presented in the paper are due to Mr. U. N. Sengupta to whom the authors' thanks are due.

REFERENCES

- Annual Weather Review Pt. A* (1938)
A. O. A. C. (1935)
Artis, B. (1916). Nitrogen, chlorine and sulphates in rain and snow. *Chem. News*, 113, 2928, 3-5
Barr, W. (1914). The influence of ocean spindrift and blown spray on the chlorine content of inland ground waters—original not seen. *Expt. Sta. Rec.*, 31, 813
Blanford, W. T. (1876). On the physical geography of the Great Indian Desert. *J. Asiatic Soc. Bengal*, 45, 2, 99
Buck and Wright (1897). Quoted in *Agricultural Ledger* 7, 5

- Crowther, C. and D. W. Stewart (1912). The distribution of atmospheric impurities in the neighbourhood of an industrial city. *J. Agric. Sci.*, 5, 399-407
- Gee, E. R. (1934). The saline series of North West India. *Curr. Sci.* 2, 12, 457-463
- Hansen, F. (1931). Investigations of rain water—original not seen. *Expt. Sta. Rec.*, 66, 312
- Jackson, D. D. (1918). The normal distribution of chlorine in the natural waters of New York and New England. *U. S. Geol. Surv. Water Irrig. Paper*, 144, 31
- Jorissen, W. P. (1906). Amount of chlorine in rain water. *J. Chem. Soc.*, 90, 525, II, 486
- Kinch, E. (1900). Amount of rain water collected at Cirencester. *J. Chem. Soc.*, 77, 457, 1271-1273
- Knox, W. K. (1915). Nitrogen and chlorine in rain and snow. *Chem. News*, 111, 2280, 61-62
- La Touche, T. D. (1911). Geology of Western Rajputana : Blown Sand. *Mem. Geol. Surv. Ind.* 35, 1-43
- Lawes, J. B. (1891). Quoted in Storer's Agriculture, II, 579-580
- Leather, J. W. (1905). *Agricultural Ledger*, 8
- Passerini, N. (1894). The chlorine content of rain water—original not seen ; *Expt. Sta. Rec.* 5, 804
- Scofield, C. S. (1940). Salt balance in irrigated area. *J. agric. Res.*, 61, 17-39
- Scofield, C. S. and Headley F. B. (1921). Quality of irrigation water in relation to land reclamation. *J. agric. Res.*, 4, 265-278
- Sen, A. (1943). A note on the wind borne dust collected during the month of May 1942. *Curr. Sci.*, 12, 2, 55
- (1945). Occurrence of summer dust over Delhi. *Curr. Sci.*, 14, 10, 45
- Sengupta, U. N. ; Sen, A. ; Ukil, A. C. and Viswanath, B. (1946). Comparative studies on Indian soils—Depth distribution of soluble salts in soil profiles. *Indian J. agric. Sci.*, 16, 4
- Storer, F. H. (1897). *Agriculture*, II, 579-580
- Viswanath, B. and Ukil A. C. (1943). *Soil Map of India*

STUDIES ON THE RELATIONSHIP OF THE *BHENDI* YELLOW VEIN-MOSAIC VIRUS AND ITS VECTOR, THE WHITE-FLY (*BEMISIA TABACI* GEN.)

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(Received for publication on 20 April, 1951)

(With Plate IV)

BHENDI (*Hibiscus esculentus* L.) is a very important vegetable crop in the Bombay State and is cultivated extensively. It suffers from a virus infection namely 'yellow vein-mosaic virus'. This disease causes huge financial loss to the vegetable interests. Investigations on the disease by Uppal *et al.* [1940] showed it to be caused by a transmissible virus. The symptoms of the disease, its transmission by grafting, through the white-fly, and its host range have been fully described in an earlier communication by Capoor and Varma [1950].

Since little is known about the behaviour of white-fly as vector of plant viruses, experiments were conducted to study the various factors that influence the efficiency of *Bemisia tabaci* as vector of *bhendi* yellow vein-mosaic virus. This paper deals with this.

MATERIAL AND METHODS

The virus was obtained in 1939 from a severely diseased *bhendi* plant growing in a field at the Agricultural College Farm, Poona. Since then, it has been maintained by repeated transfers to healthy *bhendi* plants by means of white-flies. Virus free colonies of the white-fly were established thus. Large number of white-fly adults were collected from healthy tomato plants and made to oviposit on sunflower seedlings. First instar nymphs, hatching out from these eggs were transferred to healthy tobacco and cotton plants grown under muslin covers in the glass-house. The pure lines developed from the above stock have been maintained throughout and all the insects used in these experiments were taken from these colonies.

The method of feeding white-flies individually or in groups on a particular leaf of a test plant has been fully described previously [Capoor and Varma 1950]. After the flies had been fed on a particular leaf of a test plant the leaf was marked by a small tag label and clipped off before the time when new flies were expected to emerge from the eggs laid by the experimental insects. In this way, a general infestation of the glass-house by the white-flies was well prevented. Additional precaution was taken by regularly fumigating the glass-house by 'Corry's white-fly death' fumigant.

EXPERIMENTAL RESULTS

Relation of the number of white-flies to percentage infection

Freshly emerged white-flies rendered viruliferous by feeding on diseased plants for 12 to 24 hours were used in these experiments. The required number of insects were fed in micro-cages on test plants for definite periods and then killed by puffing a little quantity of cyanogas into the micro-cage. The test plants were removed to another glass-house and watched for the appearance of the disease. Uninoculated checks or control plants selected from the same lot were kept along with the test plants. The results of these experiments are given in Table I.

TABLE I

Relation of number of viruliferous white-flies to the percentage infection

Number of white-flies per plant	Number of plants infected in each test			Total	Percentage	Number of days after inoculation when disease appeared (Range)
	A 19-10-39	B 16-7-40	C 19-1-41			
	*					
1	2/5	2/6	1/6	5/17	29.4	21 to 35
3	4/5	2/6	3/6	9/17	52.9	15 to 35
5	5/5	4/6	3/6	12/17	70.5	14 to 35
10	5/5	6/6	5/6	16/17	94.1	14 to 30
15	5/5	6/6	6/6	17/17	100.0	14 to 28
20	5/5	6/6	6/6	17/17	100.0	11 to 24
30	5/5	6/6	6/6	17/17	100.0	14 to 21
50	5/5	6/6	6/6	17/17	100.0	11 to 28

*Numerator=Number of plants diseased

Denominator=Number of plants inoculated

The results show that percentage infection was higher in plants inoculated with groups of white-flies and though transmission resulted in thirty per cent of the plants inoculated with individual insects, the minimum number of flies required to secure cent per cent transmission was near about ten.

Kirkpatrick [1930] was able to get positive transmission of cotton leaf curl by using 50 to 200 white-flies. Pruthi and Samuel [1937] were able to obtain a fair amount of infection in tobacco plants by inoculating them with two to six white-flies per plant and concluded that with maximum number of flies, the incubation

period of tobacco leaf curl virus was not generally the shortest. Storey and Nicholas [1938] transmitted Cassava mosaic by using 5 to 100 white-flies per plant. The data obtained with *bhendi* yellow vein-mosaic virus seems to be strikingly similar to that got by Orlando and Silbreschmidt [1946] who concluded that the transmission of Abutilon Virus I by individual specimens of *Bemisia tabaci* was low and improved quickly by increasing the number of insects and reached the maximum by using ten insects per plant. Costa and Bennett [1950] have further confirmed these results in the case of *Euphorbia* mosaic virus.

Feeding period required by white-flies to secure virus from diseased plants

White-flies were fed on diseased plants for periods ranging from 15 minutes to 18 hours and then tested by placing 15 insects in one micro-cage and allowing them to feed on healthy test plants for 48 hours. The results of these tests are shown in Table II.

TABLE II

Feeding period required by the white-flies to secure virus

Feeding period on diseased plant	Plants infected in each test					Total	Percentage
	A	B	C	D	E		
				*			
15 minutes	..	..	..	0/10	0/10	0/20	0-0
30 minutes	..	..	0/5	0/10	0/10	0/25	0-0
1 hour	2/5	1/5	1/5	5/10	8/10	17/35	48-5
2 hours	3/5	4/5	5/5	9/10	10/10	31/35	88-5
3 hours	5/5	5/5	5/5	10/10	10/10	35/35	100-0
4 hours	5/5	5/5	5/5	..	..	15/15	100-0
6 hours	5/5	5/5	5/5	..	..	15/15	100-0
12 hours	5/5	6/6	..	..	..	11/11	100-0
18 hours	5/5	6/6	..	..	..	11/11	100-0

*Numerator=Number of plants infected

Denominator=Number of plants inoculated

These tests show that the white-flies were able to secure the virus in a feeding period of one hour or more but not in thirty minutes or less.

Kirkpatrick [1931] reported that white-flies could pick up the cotton leaf curl virus after a feeding period of three hours but shorter periods were not tested. Pruthi

and Samuel [1939] found that the white-flies could transmit the tobacco leaf curl virus after five to six hours' feeding on diseased plants. Costa and Bennett [1950] reported that the white-flies could acquire the *Euphorbia* mosaic virus in a feeding period of thirty minutes, but several hours may be required for the insects to secure a maximum charge of the virus. Possibly this interval may vary a little with the type of virus, the insect is transmitting.

Effect of fasting on the ability of the white-flies to secure virus from diseased plant

Watson [1938] however, reported that *Myzus persicae* was more likely to transmit *Hyoscyamus* Virus 3 if made to fast just before feeding on an infected plant. This indicated that the time required by an insect for picking up virus from diseased plants depends a good deal on the condition of vector before it has access to the source of infection.

In experiments made to determine the effect of fasting on the ability of the white-flies to secure virus from diseased plants trials were made with individual flies which were subjected to the following treatments :

Preliminary fasting	None, 1 hour, 2 hours, 4 hours and 6 hours
Infection feeding	15 min., 30 min., 1 hour, 2 hours and 4 hours
Time on healthy plants	Constant—24 hours

Insects were starved in clean glass vials before noon and ten infection trials were made for each of the twenty combinations of treatments and the whole experiment was repeated thrice. The test plants were kept under observation for 50 days. The results of 30 infection trials for each combination of treatments are given in Table III.

TABLE III

Effect of preliminary fasting on the percentage of white-flies becoming infective after varying infection feeding periods

Preliminary fasting period	Number of insects becoming viruliferous after indicated infection feeding periods					Total	Per cent Infection
	15 mts.	30 mts.	1 hour	2 hours	4 hours		
None	0	0	1	2	5	8	5.3
1 hour	0	1	4	5	10	20	13.3
2 hours	0	2	5	7	10	24	16.0
4 hours	0	7	12	14	17	50	33.3
6 hours	0	8	13	18	19	58	38.6
Total	0	18	35	46	61	160	..
Per cent infection	0	12.0	23.3	30.6	40.6	..	..

The data show that the preliminary fasting markedly increased the efficiency of white-flies as vectors, for, more than twice the number of insects became viruliferous after starvation for one hour than when no fasting had been given. The increase

was less marked for fasting period of more than four hours duration. In every case the effect of preliminary fasting became more obvious as time for infection feeding increased.

The low percentage of infections obtained after an infection feeding period of 30 minutes even after one or two hours fasting can be explained in part due to the insects taking some time to settle down for feeding. Further, Capoor [1949] has shown that in a feeding time of 30 minutes or less, most of the stylets of the white-flies do not reach phloem tissue, and the insects are therefore unable to obtain an adequate charge of the virus.

Feeding period required by the white-flies to transmit the virus

White-flies that had been fed for 24 hours on diseased plants were used to determine the feeding period required for viruliferous insects to transmit the virus to healthy *bhendi* plants. They were confined in groups of twenty on test plants and allowed to feed for different intervals and then destroyed. The plants were kept in insect proof glass-house until observations were over. The results of these tests are given in Table IV.

TABLE IV

Feeding period required for white-flies to transmit bhendi yellow vein-mosaic virus

Feeding period on test plants	Number of plants becoming diseased in each test						Total	Percentage
	A	B	C	D	E	F		
						*		
5 minutes	..	..	..	..	..	0/12	0/12	..
30 minutes	..	..	..	..	..	2/12	2/12	16.6
1 hour	..	3/5	2/5	5/6	3/6	6/6	19/28	67.8
2 hours	..	5/5	5/5	6/6	5/6	6/6	27/28	96.4
3 hours	..	5/5	5/5	6/6	6/6	6/6	28/28	100.0
4 hours	5/5	5/5	5/5	..	..	..	15/15	100.0
5 hours	5/5	5/5	..	..	..	..	10/10	100.0
6 hours	5/5	5/5	..	..	..	..	10/10	100.0
12 hours	5/5	5/5	..	..	..	..	10/10	100.0
18 hours	5/5	..	..	..	..	..	5/5	100.0
24 hours	5/5	..	..	..	..	..	5/5	100.0

*Numerator=Number of plants diseased
Denominator=Number of plants inoculated

The results show that during a feeding period of 30 minutes, some insects could transmit the virus but not in a feeding period of five minutes. This was probably due to two causes. Firstly, insects that were not hungry would feed very indifferently or not feed at all and those that tried to feed would lose some time in orientation.

In another series of experiments, the effect of post-infection fasting on the efficiency of the white-flies to transmit the virus was investigated. Large number of white-flies were fed on diseased *bhendi* plants for 20 hours and then starved for different periods. After varying periods of post-infection fasting, these insects were fed in groups of twenty in micro-cages on healthy test plants for 5, 10, 20 and 30 minutes. The results are given in Table V.

TABLE V

*Effect of post-infection fasting on the time required for white-flies to transmit the virus
(Total of three tests)*

Post infection fasting	Number of test plants becoming diseased after feeding periods of			
	5 minutes	10 minutes	20 minutes	30 minutes
2 hours	0/5	1/10	3/10	8/10
3 hours	0/5	5/10	7/10	10/10
4 hours	0/5	6/10	7/10	9/10

*Numerator=Number of plants diseased
Denominator=Number of plants inoculated

The results of these tests show that after a post-infection fasting of two hours several insects were able to transmit the virus to healthy plants in ten minutes. It appears that a feeding period of five minutes is not enough for insects to transmit the virus. Post-Infection Fasting Period beyond three hours exhibited no appreciable increase in infectivity.

In another experiment, the effect of post-infection fasting on the capacity of individual white-flies to transmit the virus was tested. The insects were given the following treatments :

Infection Feeding	Constant—24 hours
Post-Infection Fasting	None, 1 hour, 2 hours, 4 hours, 6 hours and 8 hours
Time on test plants	10 minutes, 20 minutes and 1 hour

Thirty-six infection trials were made for each of the eighteen combinations and the results are given in Table VI.

TABLE VI

Effect of post-infection fasting on the time required by the white-flies to transmit the virus

Post infection fasting	Number of plants becoming diseased after feeding periods of				Per cent Infection
	10 minutes	20 minutes	1 hour	Total	
None	0	0	3	3	2.8
1 hour	2	4	8	14	12.9
2 hours	4	7	12	23	21.3
4 hours	11	15	19	45	41.6
6 hours	12	16	19	47	43.6
8 hours	14	17	20	51	47.2
<i>Total</i>	43	59	81	183	..
Per cent infection	19.9	27.3	37.3	..	..

The results obtained from these tests are similar to those summarised in Table V. A feeding period of ten minutes on healthy plants was enough for the transmission of infection, but no appreciable improvement was observed by increasing the fasting period beyond four hours.

Costa and Bennett [1950] reported that though white-flies could transmit *Euphorbia* mosaic virus to healthy plants in ten minutes and longer they could not do so in five minutes and though infection percentage increased considerably in 30 to 60 minutes, it reached 100 per cent only in 24 hours period. In tests with *bhendi* yellow vein-mosaic virus, the viruliferous white-flies gave almost 50 per cent infection after feeding period of 30 minutes provided they had fasted for at least three hours before feeding on healthy plants.

The fact that white-flies require a relatively shorter period to transmit the yellow vein-mosaic virus as compared to the time taken by them to acquire the virus from the diseased plants indicates that most probably the virus is introduced in the mesophyll cells accidentally. The course of stylets in mesophyll is inter-cellular and the infection must be merely a chance.

Incubation period of the virus in the white-fly

The term 'incubation period' or the latent period as employed by Leach [1940] signifies the delay in the development of infection ability of a vector and it is to indicate this interval that the term has been used in these studies. For determining

the incubation period of *bhendi* yellow vein-mosaic virus in its vector, three types of tests were conducted which are briefly described below :

- (a) White-flies were fasted for one hour and then given an infection feed of one and two hours. Twenty insects were put in one micro-cage and fed on healthy test plants for intervals varying from one to twenty-two hours.
- (b) White-flies were fasted as above and fed on diseased plants for periods ranging from 2 to 10 hours. Five lots of insects (in groups of 20) were tested for each period by allowing them to feed on healthy test plants for one hour only.
- (c) After preliminary fasting for one hour, white-flies were caged on diseased plants for one and two hours and then transferred at hourly intervals to successive healthy plants for nine hours. In these tests the number of insects in each micro-cage was little over 20. Frequent transfers at short intervals resulted in some mortality and therefore the number of flies feeding on healthy plants coming at the end of each test was about 20. The insects surviving at the end were allowed to feed overnight on a healthy plant.

These experiments were repeated several times at different periods of the year and the results are summarized in Tables VII and VIII respectively.

TABLE VII
Incubation period of yellow vein-mosaic virus in the white-fly

Experiment	Feeding period on diseased plants (hours)	Feeding period on healthy plants (hours)	Total feeding period on both (hours)	Plants infected in each test
(A)				*
Tests conducted from 22-9-40 to 3-12-40	1	1	2	0/6
	1	2	3	0/6
	1	3	4	0/6
	1	4	5	0/6
	1	5	6	0/11
	1	6	7	0/11
	1	7	8	1/5
	1	8	9	3/5
	1	9	10	3/5
	1	10	11	2/5
	1	11	12	4/5
	2	1	3	0/5
	2	2	4	0/5
	2	3	5	0/5
	2	4	6	0/10
	2	5	7	0/15
	2	6	8	4/15
	2	7	9	7/15
	2	8	10	9/15

*Numerator=Number of plants diseased

TABLE VII—*contd.*

Experiment	Feeding period on diseased plants (hours)	Feeding period on healthy plants (hours)	Total feeding period on both (hours)	Plants infected in each test
(B) 13-11-41	2	9	11	6/15
	2	10	12	12/15
	2	11	13	15/15
	2	12	14	10/10
	2	14	16	5/5
	2	16	18	5/5
	2	18	20	5/5
	2	20	22	5/5
	2	22	24	5/5
	2	1	3	0/5
	3	1	4	0/5
	4	1	5	0/5
	5	1	6	0/5
	6	1	7	0/5
	7	1	8	2/5
	8	1	9	3/5
	9	1	10	2/5
	3	1	4	0/5
	4	1	5	0/5
	5	1	6	0/5
1-2-42	6	1	7	0/5
	7	1	8	1/5
	8	1	9	3/5
	9	1	10	3/5
	10	1	11	4/5

Denominator=number of plants inoculated

TABLE VIII

Incubation period of yellow vein-mosaic virus in the white-fly

Experiment	White-fly group No.	Feeding period on diseased plants (hours)	Infections on test plants caused in successive one hour feeding periods									Infection on plant to on which insects fed over-night at the end
			1	2	3	4	5	6	7	8	9	
(C)			*									
18.3.41	1	1	—	—	—	—	—	—	—	—	—	+
	2	1	—	—	—	—	—	—	—	+	+	+
	3	1	—	—	—	—	—	—	—	+	+	+
	4	1	—	—	—	—	—	—	—	—	—	—
	5	1	—	—	—	—	—	—	+	+	+	+
	6	1	—	—	—	—	—	+	+	+	—	+
	7	1	—	—	—	—	—	—	—	+	+	+
	8	1	—	—	—	—	—	—	—	+	+	+
	9	1	—	—	—	—	—	—	—	—	—	+
25.4.41	1	1	—	—	—	—	—	—	—	+	+	+
	2	1	—	—	—	—	—	—	—	—	—	—
	3	1	—	—	—	—	—	—	+	+	+	+
	4	1	—	—	—	—	—	—	—	+	+	+
	5	1	—	—	—	—	—	—	—	—	+	—
	6	1	—	—	—	—	—	—	—	+	+	+
	7	1	—	—	—	—	—	—	—	—	—	—
	8	2	—	—	—	—	—	+	+	+	+	+
	9	2	—	—	—	—	—	+	+	+	+	+
	10	2	—	—	—	—	—	—	—	—	+	+
	11	2	—	—	—	—	—	—	+	+	+	+
	12	2	—	—	—	—	—	—	+	+	+	+

*+ Sign indicates positive infection

— Sign indicates negative infection

The above data show that under the conditions of the experiment the minimum incubation period of the virus in the white-fly was seven hours.

Tests were also made with individual white-flies. After preliminary fasting for four hours the insects were fed on diseased plants for two hours. Individual insects in micro-cages were confined on healthy plants and divided into twenty four groups of eight plants each. From test plants comprising group No. 1, white-flies were removed after one hour, from group No. 2 after two hours and so on at intervals of one hour until the insects from the last group had been removed after twenty four hours. The experiment was repeated twice and the results are given in Table IX.

TABLE IX

Incubation period of the yellow vein-mosaic virus in the white fly

Feeding period on healthy plants (hours)	Number of white-flies proving infective in respective trials		Total
	I	II	
	*		
1	0/8	0/6	0/14
2	0/8	0/6	0/14
3	0/8	0/6	0/14
4	0/8	0/6	0/14
5	0/8	0/6	0/14
6	0/8	0/6	0/14
7	1/8	0/6	1/14
8	3/8	1/6	4/14
9	1/8	2/6	3/14
10	4/8	1/6	5/14
11	4/8	2/6	6/14
12	3/8	3/6	6/14
13	4/8	2/6	6/14
14	3/8	4/6	7/14
15	5/8	4/6	9/14
16	5/8	5/6	10/14
17	4/8	5/6	9/14
18	6/8	3/6	9/14
19	4/8	5/6	9/14
20	8/8	4/6	12/14
21	7/8	5/6	12/14
22	7/8	5/6	12/14
23	8/8	6/6	14/14
24	6/8	6/6	12/14

*Numerator=Number of plants diseased
Denominator=Number of plants inoculated

These results conclusively show that the minimum incubation period of the virus in the white-fly is 7 hours. The number of insects becoming infective at the end of the minimum incubation period is, however, small and it varies a good deal among individual white-flies.

Kirkpatrick [1931] found the incubation period of the cotton leaf curl virus in the white-fly to be 6 hours. Costa and Bennett [1950] recorded a great variation in the incubation period of *Euphorbia* mosaic virus in the white-fly. 'In 11 out of 13 sets the indicated incubation period was more than 8 hours. In eight of these tests it appeared to be between 8 to 24 hours and in three between 24 and 48 hours. However in two sets, the white-flies transmitted the virus after 4 to 5 hours incubation period, ceased to transmit and then resumed transmission later.'

Period of retention of the virus by the white-fly

Kirkpatrick [1931] stated that (a) *Bemisia gossypiperda*, M. & L., could infect cotton plants even after feeding for 72 hours on *Dolichos lablab* plants, and (b) the insects could retain the virus for 7 days even after feeding on healthy cotton plants. Costa and Bennett [1950] reported that though individuals differed in their ability to transmit the virus, evidence was obtained that the *Euphorbia* mosaic virus persisted in the vector for at least 20 days.

The normal life of a female white-fly at Poona is about three weeks and the males live for a much shorter period. The following two types of experiments were done to determine the period for which white-flies once proved to be infective could retain the *bhendi* yellow vein -mosaic virus while feeding on healthy plants.

(A) Populations of freshly emerged white-flies were fed on diseased plants for 20 hours and then transferred to healthy sea island cotton plants kept under a muslin cage in separate glass-house. From this stock 20 to 30 insects were removed daily, put in a micro-cage and tested for infection by feeding on healthy *bhendi* seedlings for three hours only. The experiment was concluded after the 19th day by which time the stock of the white-flies on cotton plants had been exhausted. The plants on which this stock was kept were changed on the 10th day in order to avoid mixing of the viruliferous insects with fresh ones that might emerge from the eggs laid by the white-flies on the cotton plants. The results of the experiment are given in Table X.

(B) Freshly emerged females were fertilized by keeping them with males for one day. They were then given Infection Feeding for 24 hours and were confined individually in micro-cages on healthy *bhendi* seedlings and transferred daily to new plants till they died. The experiment was repeated twice with fifty white-flies, but records of twenty two insects which survived the longest in both the tests are given in Table XI.

The tests conducted show that white-flies were infective till the 19th day without having recourse to the source of infection second time.

In tests with individual white-flies it was found that when confined in micro-cages on *bhendi* plants, the insects died after two to three days and the mortality occurred mostly at night. This difficulty appeared to be due to the accumulation of carbon-dioxide inside the cages and was overcome by constantly replacing at night, the foul air in the micro-cages with fresh air by means of a simple device. A rubber cork was fitted to the lower end of the micro-cage. Through this two capillary tubes

TABLE X

Retention of the bhendi yellow vein-mosaic virus by the white-fly

Date of experiments.	Infection on healthy plants after indicated days																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
11-2-41 . .	*+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
16-5-42 . .	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+

*+sign indicates positive infection
—sign indicates negative infection

TABLE XI

Retention of the yellow vein-mosaic virus by the white-fly

Female number	Infection on test plants on successive days																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	+	+	—	+	+	—	+	+	—	+	+	—	+	—	+	+	—	—	—	D		
2	—	+	+	—	—	—	+	—	+	—	—	—	—	+	—	D		—	—			
3	+	+	+	—	+	+	—	—	+	+	+	—	+	+	+	—	—	+	D			
4	—	+	+	+	+	—	+	+	+	+	—	+	+	+	D							
5	+	+	+	+	+	+	—	+	+	+	—	+	+	—	—	+	+	—	D			
6	—	+	+	—	—	+	—	—	—	—	—	—	+	—	—	D						
7	+	+	—	+	+	+	+	+	—	—	+	+	—	—	—	+	—	+	—	D		
8	—	—	—	+	—	—	—	+	—	—	—	—	—	D								
9	+	+	+	+	+	+	—	+	—	+	+	—	+	—	D							
10	+	+	—	—	—	—	—	+	+	+	—	+	+	+	—	—	D					
11	—	+	+	+	—	+	+	+	+	+	+	+	—	+	+	+	+	D				
12	—	—	—	+	—	—	—	+	—	—	—	+	—	+	—	+	+	D				
13	—	—	+	+	—	—	+	+	—	+	+	+	+	—	+	—	—	+	—	—	—	D
14	+	—	—	+	+	+	+	—	+	—	+	—	—	+	—	—	—	—	D			
15	+	+	+	+	—	—	—	+	+	+	+	+	—	—	+	+	—	—	—	+	D	
16	+	+	+	+	+	+	—	+	+	—	—	+	—	—	—	D						
17	+	+	+	—	+	+	—	—	+	—	+	—	—	+	—	D						
18	+	+	—	—	—	+	+	+	—	—	+	+	+	—	+	+	+	—	—	D		
19	—	+	+	+	—	+	+	+	+	+	—	—	+	D								
20	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	D					
21	+	+	+	+	+	+	+	+	+	+	—	+	+	+	+	—	—	—	D			
22	—	—	+	+	+	—	—	—	+	+	+	—	+	+	+	—	+	—	+	D		

*+sign indicates positive infection
—sign indicates negative infection
D indicates the death of the insect

were passed. One of these was pressed a little higher up in the cage and was connected to the suction pump, which worked during the night. As a precaution the ends of glass tubes inside the micro-cage were covered with fine cloth in order to prevent the escape of insects. It was possible to work twelve cages with one pump Plate IV.

The above results show that the majority of the white-flies after an infection feeding of 24 hours are able to retain infectivity all their lives. Though in some cases the number of plants infected by the white-flies in their life time was few and in others the transmission irregular but there was hardly any indication of the loss of virus in the insects as they aged. Positive infection was obtained in some cases even on the 20th day.

The data presented by Costa and Bennett [1950] agree in principle with the results obtained for *bhendi* yellow vein-mosaic virus.

These observations further prove that *bhendi* yellow vein-mosaic virus is a persistent type of virus according to Watson and Roberts [1939].

Distribution of the virus in diseased bhendi plants

In order to determine the presence of the virus in different leaves of *bhendi* plant after inoculation the following experiments were performed.

Experiment A. Two healthy vigorously growing *bhendi* plants were selected for this study. Each of these plants had four leaves in addition to the cotyledons. The plants were inoculated on the second leaf (counting from the growing point) by allowing thirty viruliferous white-flies to feed on them for 12 hours. Hereafter the presence of the virus in leaves nos. 1, 2 and 4 on each of the plants was tested every day by allowing groups of thirty white-flies to feed on each of these leaves for 5 hours. After the insects had fed on the inoculated plants they were left for 24 hours on healthy *bhendi* seedlings. The daily test for the presence of the virus in the respective leaves of the two plants was continued till visible symptoms of yellow vein-mosaic appeared on the youngest leaf i.e., leaf no. 1.

Experiment B. As in experiment A, six *bhendi* plants, 37 days old were inoculated with infective white-flies but three of these (plant nos. 1, 2 and 3) were inoculated on the oldest leaf, i.e., leaf no. 4 and the remaining three plants (nos. 4, 5 and 6) on the youngest leaf, i.e., leaf no. 1. In these tests all the four leaves of the inoculated plants were tested for the presence of the virus as before. The results of these two experiments are given in Table XII.

The above data show that the white-flies were able to acquire the virus from the youngest leaf of the inoculated plants several days before they developed any visible symptoms of the disease. After this, the virus was readily secured from the other leaves in succession, so that it was available in the oldest leaf at the latest. In some cases the virus could not be secured from the oldest leaves at all.

Three plants from experiment B (nos. 1, 5 and 6) were further tested by the same method for the presence of the virus in their respective leaves at intervals of 15 days for 3 months from the date of appearance of initial symptoms of the disease. The results are given in Table XIII.



FIG. 1. A microcage showing arrangement for suction of foul air

TABLE XII

Distribution of yellow vein-mosaic virus in leaves of inoculated bhendi plants

Experiment.	Plant number.	Leaf inoculated.	Date of inoculation.	Date of appearance of symptoms on youngest leaf.	Dates on which white-flies could secure the virus from leaf number			
					1	2	3	4
A	1	2	14-10-41	31-10-41	25-10-41	28-10-41	Not tested	No virus
	2	2	14-10-41	1-11-41	25-10-41	25-10-41	"	1-11-41
B	1	4	9-4-42	24-4-42	19-4-42	22-4-42	26-4-42	28-4-42
	2	4	"	28-4-42	25-4-42	25-4-42	28-4-42	3-5-42
	3	4	"	24-4-42	20-4-42	24-4-42	29-4-42	No virus
	4	1	"	27-4-42	22-4-42	22-4-42	25-4-42	"
	5	1	"	29-4-42	23-4-42	29-4-42	1-5-42	3-5-42
	6	1	"	29-4-42	22-4-42	27-4-42	30-4-42	1-5-42

TABLE XIII

Distribution of yellow vein-mosaic virus in leaves of diseased bhendi plants

Date	Number of test plants infected by white-flies that had fed on various leaves of (diseased) test plants												
		Plant no. 1.				Plant no. 5.				Plant no. 6.			
		Leaf no.				Leaf no.				Leaf no.			
		1	2	3	4	1	2	3	4	1	2	3	4
May 1942	15,	* 3/3	3/3	3/3	0/3	3/3	3/3	3/3	0/3	3/3	3/3	3/3	1/3
May 1942	30,	2/2	2/2	2/2	0/2	2/2	2/2	2/2	1/2	2/2	2/2	1/2	0/2
June 1942	14,	2/2	1/2	0/2	0/2	2/2	2/2	0/2	—	2/2	1/2	0/2	0/2

*Numerator=number of plants infected

Denominator=number of plants inoculated

—sign indicates that the particular leaf was shed

These results show that white-flies were not able to secure the virus from the oldest leaf after some time. This might have been due to the fact that all the virus

moved out of this leaf (leaf no. 4) of plant no. 1 and in other cases the virus perhaps did not enter at all in the old leaf (no. 4 of plants 5 and 6) as these were inoculated on the youngest leaf.

Comparison of transmission power of male and female white-flies

For comparing the transmission power of male and female flies, freshly emerged insects were fed on diseased *bhendi* plants for forty eight hours and then tested for the presence of virus by caging them individually on healthy test plants for twenty four hours. The results are given in Table XIV.

TABLE XIV

Transmission power of male and female white-flies

Date	Sex	Number tested	Number infective
14 July, 1941	Male	100	52
	Female	100	81
8 December, 1941	Male	50	31
	Female	50	42
4 May, 1942	Male	50	30
	Female	50	33
26 May, 1942	Male	50	28
	Female	50	38

The above results show that out of a total of 500 white-flies tested, only 335 insects proved infective out of which 141 were males and 194 females. The females thus appeared to be better than males in the matter of virus transmission. Orlando and Silbrschmidt [1946] also found the females better than males in their ability to transmit the *abutilon* virus I. Costa and Bennett [1950] found the transmission efficiency of the female white-flies almost twice those of males.

SUMMARY

The relation of the white-fly (*Bemisia tabaci* Gen.) to the transmission of *bhendi* (*Hibiscus esculentus*) yellow vein-mosaic virus has been studied.

Though single insects were able to transmit the virus, the minimum number of flies required to produce cent per cent infection is about ten. The white-flies could secure the virus from diseased plants after feeding for one hour and the viruliferous insects could transmit the virus to healthy plants after feeding on them for 30 minutes.

Preliminary Fasting up to a period of four hours seemed to improve the efficiency of white-flies as vectors. Longer fasting periods have been shown to be ineffective. Some of the white-flies could secure the virus after feeding on source of virus for 30 minutes but never in shorter period.

Post infection fasting was also effective up to four hours and some of the white-flies were able to transmit the virus to healthy plants after feeding for 15 minutes only.

The minimum incubation period of the virus in the white-flies was 7 hours but the number of insects becoming infective after this interval was small.

The white-flies which had fed on diseased plants for 12 to 24 hours remained infective throughout their lives.

The white-flies were able to acquire virus from the youngest leaf of an inoculated *bhendi* plant a few days prior to the manifestation of symptoms of the disease.

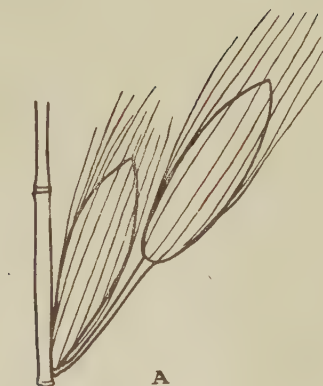
The female white-flies have been found to be only slightly better than the males with regard to the transmission of the virus.

ACKNOWLEDGMENTS

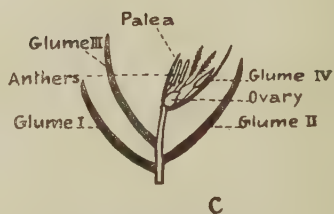
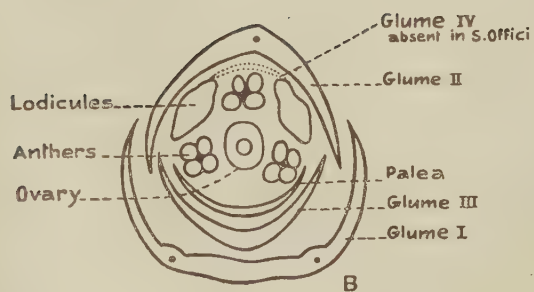
The author wishes to place on record his deep indebtedness to Dr. B. N. Uppal for help and guidance throughout the progress of the work. Thanks are due to Dr. M. K. Patel and Dr. S. P. Capoor for help in the preparation of the manuscript. The generosity of the Indian Council of Agricultural Research is gratefully acknowledged for financing a scheme of research under which this work has been finalized.

REFERENCES

- Capoor, S. P. (1949). Feeding methods of the cotton white-fly. *Curr. Sci.* **18**, 82-83
- Capoor, S. P. and Varma, P. M. (1950). Yellow vein-mosaic of *Hibiscus esculentus* L. *Indian J. Agric. Sci.*, **20**, 217-230
- Costa, A. S. and Bennett C. W. (1950). White-fly transmitted mosaic of *Euphorbia prunifolia*. *Phytopath.* **40**, 266-283
- Kirkpatrick, T. W. (1930). Preliminary note on Leaf-crinkle of cotton in the Gezira Area, Sudan. *Bull. Entom. Res.*, **21**, 127-137
- (1931). Further studies on Leaf-curl of cotton in the Sudan. *Bull. Entom. Res.*, **22**, 323-363
- Leach, G. L. (1940). *Insect transmission of Plant Diseases*. McGraw-Hill, New York
- Orlando, A., and K. Silbreschmidt (1946). Estudos Sobre a disseminacao natural do virus 'da' clorose infecciosa das malvaceas (*Abutilon* Virus 1, Baur.) e a su relacao com o insecto-vector *Bemisia tabaci* (Genn.) (Homoptera Bleyrodidae) Arquivos do Instituto Biologico. **17**, 1-36
- Pruthi, H. S. and Samuel, C. K. (1937). Entomological Investigations on the Leaf Curl Disease of tobacco in North Bihar, I and II. *Indian J. agric. Sci.*, **7**, 659-670
- (1939). Entomological Investigations on the Leaf Curl Disease of tobacco in Northern India. III. *Indian J. agric. Sci.*, **9**, 223-275
- Storey, H. H. and Nicholas R. F. W. (1938). Studies on the mosaic disease of Cassava. *Ann. Appl. Biol.* **25**, 790-806
- Uppal, B. N., Varma, P. M. and Capoor S. P. (1940). Yellow vein-mosaic of *bhendi*. *Curr. Sci.*, **9**, 227-228
- Watson, M. A. and Roberts F. B. (1939). A comparative study of the transmission of Hyoscyamus Virus 3, Potato Virus Y and Cucumber Virus 1, by three species of aphids. *Proc. Roy. Soc. B.* **127**, 543-576



Pedicelled and sessile spikelets



An expanded spikelet

Floral diagram of spikelet

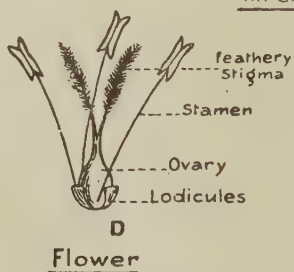


FIG. 1. Floral parts of sugarcane.

CYTO-GENETICS OF SUGARCANE

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(Received for publication on 27 March, 1951)

(With Plates V—XI)

THE sugarcane in cultivation in India are broadly divisible into two groups, the thin canes of the sub-tropical North and the 'Noble' canes of tropical India. Botanically the former are included under the species *Saccharum barberi* and the latter under *S. officinarum*. Though both these species are popularly called sugarcane, they differ from each other in certain features which may be regarded as fundamental. Generally even the same species when grown in different environmental conditions may show marked differences. But these affect only the vegetative parts of the plant. The reproductive portions, namely, the floral regions, do not show any change in their configuration or plan of construction. The bean flower for instance will present the same appearance wherever it is grown; it will have the same parts in the same order of arrangement and show the same plan of symmetry. Its stem and leaves, however, may show variation to such a degree as even to make it difficult to be recognized. Hence it is the floral region that is of the utmost importance in establishing the identity of a species and its relationship.

I. Sugarcane: Some external features and their morphological significance

In the sugarcane, the flowers occur in their thousands, to form the arrow (Plate VI, fig. 2 A) (inflorescence). As in other grasses the unit is a spikelet, two of which occur together at each node, one of them having a stalk and the other none (Plate V, fig. 1 A). Each spikelet consists of a definite number of glumes in the axil of the innermost of which the flower is situated (Plate V, figs 1, B and C). Though this is the general plan of construction, the two species of cultivated canes show differences in some important details. Of the two spikelets, the one without the stalk (sessile) is older in the 'Noble' cane, while it is the stalked spikelet that is older in the North Indian canes. In the matter of the number of glumes in each spikelet, *S. barberi* has four, whereas in *S. officinarum* usually the fourth glume is absent.

The flower itself is highly reduced, the usual showy parts, the sepals and petals, being conspicuous by their absence. It consists of those parts which are directly concerned in reproduction and for which the flower is intended. There are three stamens and an ovary with a single ovule in it, which after fertilization becomes the seed (Plate V, fig. 1, D and Plate VI, fig. 2 B). There are two structures, the lodicules which may be regarded as representing the highly reduced petals and sepals. These and other differences in the floral region coupled with some in the vegetative parts, are full of significance, to the morphologist who seeks to study inter-relationships. Such a study would reveal some interesting things. For instance, while the North Indian and tropical canes of South India differ from one another in these details, the wild cane, namely *S. spontaneum*, shares these characters with the North Indian

canes. The other likely wild relatives of the sugarcane are *Sclerostachya*, *Narenga* and *Erianthus*. Obviously for establishing relationships, many things, in addition to these morphological details, will have to be studied and taken into consideration.

II. *Breeding in relation to cytogenetics*

Any breeding work to be carried out on scientific lines must involve a knowledge of genetics and cytology. The science of genetics seeks to discover why for instance a bean seed, when sown gives rise to a bean plant and not anything else and how it also happens that one bean plant is not exactly like another. This is intimately related to cytology which is a study of the minute living units, the cells, of which plants and animals are constructed. The cells contain a dense spherical body the nucleus, lying in a viscid fluid, the cytoplasm. It has the character of heredity in itself in that it determines what the offspring is to be like. This is capable of direct demonstration in some lower plants and animals. For instance it is possible to remove the nucleus from the egg of Sea Urchin and fertilize it with sperm of another species. The resulting larva is an exact smaller edition of the male parent from which it had derived the nucleus and shows no influence of its female parent from which it had derived its cytoplasm. Similar transplantation experiments in lower organisms between parts containing nuclei and those not having them show definitely that it is the nucleus that is responsible for the transmitting of characters. The nucleus is composed of a definite number of threads, the chromosomes, on which are located the genes which are the particles concerned in the transmission of hereditary characters. The physical basis for the laws of heredity is to be found in these chromosomes and their behaviour.

III. *The nucleus in vegetative multiplication*

In vegetative reproduction or clonal propagation, such as is almost the rule in sugarcane, the whole of each clone is derived from a piece of one individual and so there is complete uniformity among all the clones. The cytological basis for this is that the cells of which the bud is composed, go on dividing repeatedly accompanied by differentiation to form the daughter cane. This division that takes place repeatedly is mitotic. The chromosomes in the cells composing the body of the plant (somatic chromosomes) are constant for any particular species of plant. In the 'Noble' cane, *S. officinarum*, the somatic number is 80. During the division of the nucleus which precedes cell division, each one of these chromosomes separates into two exact longitudinal halves, the chromatids, one half going to one pole and the other to the opposite, and never will the divided two halves of a chromosome go to the same pole (Plate VI, fig. 2, 9-13). The two daughter nuclei that result, consequently contain the same number of chromosomes. Whatever may be the number of divisions undergone, so long as this mitotic method of division is resorted to, the same number of chromosomes would be kept up, and since the daughter cells of a division are an exact replica of the mother cell, all the genes contained in the latter are present in the daughter in the same number and arrangement and hence the uniformity of individuals resulting from clonal propagation. The number of chromosomes in the mitoses of one individual and of the whole species is constant.

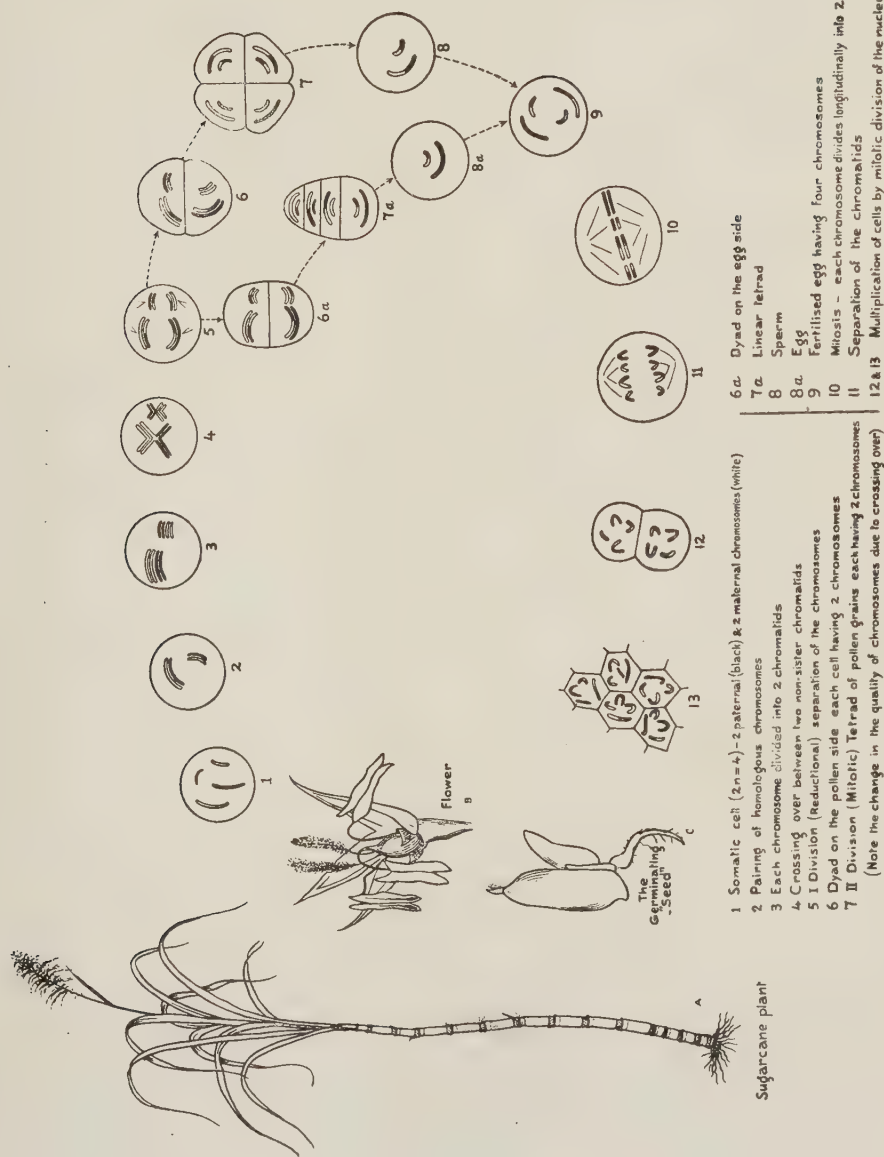


FIG. 2. Chromosome cycle in the life history of Sugarcane (only four Chromosome shown).

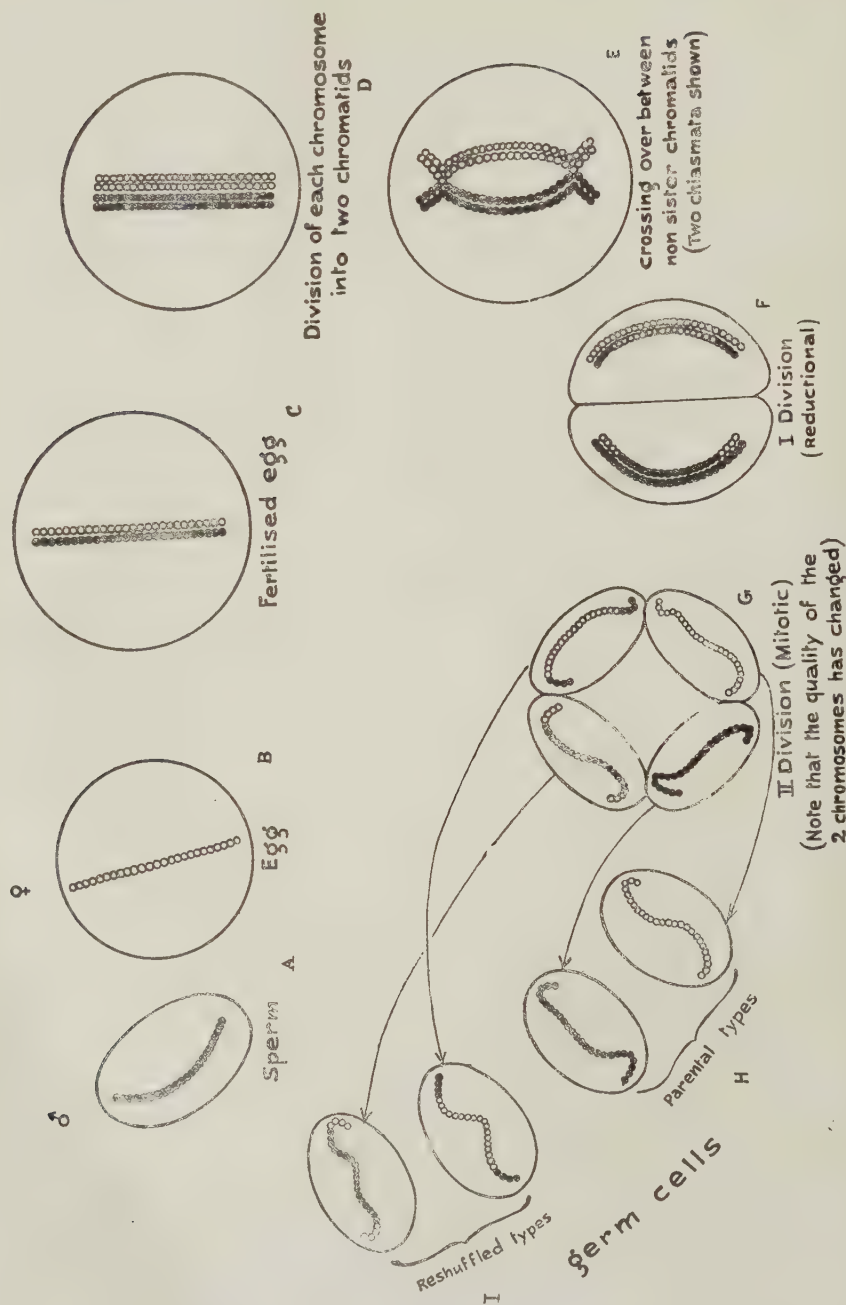


FIG. 3. Fertilization and meiosis: origin of qualitative changes in chromosomes.

IV. *The nucleus in sexual reproduction*

In sexual reproduction a sperm nucleus from a pollen grain (Plate VII, fig. 3 A) enters an egg cell (Plate VII, fig. 3 B) which is many times larger and fuses with the female nucleus. The nucleus of the fertilized egg is thus of mixed origin (Plate VII, fig. 3 C). The new organism develops from this and shows the characters father and mother. Thus the somatic cells of the resulting individual contain two similar sets of chromosomes, one from the egg and the other contributed by the sperm (Plate VI, 1 and 2). In the 'Noble' sugarcanes, 40 chromosomes from the egg nucleus combine with 40 corresponding ones from the pollen nucleus, to give 80 in the embryo, which develops into the sugarcane plant.

In the formation of these germ cells by the parent there must have taken place a process of reduction or a halving of the chromosome number to compensate for the doubling that takes place during fertilization. This reduction division of meiosis, is inevitable in the cell history, wherever there is sexual reproduction, as otherwise the chromosome number would go on duplicating *ad infinitum* from generation to generation. This takes place in the sugarcane, as in all higher plants, during the formation of the reproductive cells, pollen grain and embryo sac. Meiosis consists of two divisions of the nucleus, with only one division of the chromosomes (Plate VII, fig. 3). First, the chromosomes make contact and begin to pair (Plate VII, fig. 3 C); of each pair one is from the sperm and the other is from the egg, which had fused in fertilization to give the plant, from which the germ cells are now being organized. Thus instead of the diploid or $2n$ number of chromosomes of mitosis there is a halved or haploid n number of bivalents (Plate VI, 2). And instead of the paired sister halves or chromatids of mitosis produced by reproduction of a single chromosome, there are paired homologous chromosomes brought together by attraction. Suddenly this attraction is followed by repulsion. All the pairs separate. At the same time each chromosome has divided into a pair of chromatids (Plate VI, 3; Plate VII, fig. 3 D). The chromosomes remain in contact at certain points at which the chromatids exchange partners. Under the strain of coiling the partner chromatids break at corresponding points. They uncoil and rejoin in new combinations (Plate VI, 4 and 5; Plate VII, fig. E). The two chromosomes of each bivalent are separated and each nucleus has the haploid or reduced number of chromosomes. On account of the exchange of partners that took place prior to separation, the two chromatids of each chromosome are not throughout sister chromatids. Some portions of the chromosomes are made up of sister chromatids, the others are composed of chromatids from partner chromosome (Plate VII, fig. 3 F). The two daughter nuclei at once divide again, by mitosis (Plate VII, fig. 3, F and G). The chromosomes are already double and the two chromatids of each chromosome separate. Thus four daughter nuclei having the halved number of chromosomes are derived from the mother cell which contained the diploid number of chromosomes (Plate VII, fig. 3, H and I). Meiosis is the same whether it is on the pollen side or on the egg side. The only difference is that whereas in the former all the four pollen grains resulting from the reduction division of the pollen mother cell are functional (Plate VI, fig. 2, 6-8), on the side of the egg three

usually degenerate, and only one survives, and that is the embryo sac within which the egg is organised (Plate VI, fig. 2, 6a-8a).

V. Chromosomal basis of heredity

For the plant breeder it is meiosis that is of the utmost importance. The pairing chromosomes are of similar size and shape and are derived from opposite parents in which they have corresponding structures and functions. The four germ cells produced by meiosis are alike only in having the reduced or halved chromosome number (Plate VII, fig. 3, H and I). But in all other respects their nuclei are different. The arrangement of the paired chromosomes (bivalents) has been at random, so that paternal and maternal chromosomes would have been assorted at random also. Their parts have also been reassorted and exchanged by crossing over. It means that the minute hereditary particles, the genes, which are arranged linearly on the chromosomes have been exchanged between paternal and maternal chromosomes, leading to a recombination of hereditary differences. Each mother cell will have given rise to four germ cells, different from one another and different from those produced by any of the mother cells. Thus in sexual reproduction the occurrence of differences between individuals is inevitable. These variations are not only maintained from generation to generation, but also rearranged and redistributed so as to make every varying individual unique. In self fertilized plants, where the male and female germ cells (which ultimately fuse) come from the same or different flowers of one parent plant, the differences among individuals in the progeny are very slight. And if this self fertilization is a regular feature, generation after generation, then we get a pure line or true breeding line. But in cross pollinated plants the variations are more accentuated and wide spread. These variations are the principal working tool of the plant breeder. But before these differences are made use of, it has to be ensured that they are due to hereditary causes and not due to environment. The importance of cytogenetics lies in being able to correlate observed breeding results with chromosomal behaviour. In other words instead of breeding being a hit or miss affair, it is sought to be put on a scientific plane.

VI. Some cyto-genetical features of sugarcane

a. *Clonal propagation.* Sugarcane exhibits several cyto-genetical features, which are at once the hope and despair of the breeder. Of these the most useful is its being asexually propagated. Any good form that we may get by accident (gene mutation) or by hybridisation can at once be fixed, inasmuch as it can be propagated asexually. For instance, among the hybrids between *S. officinarum* and *S. spontaneum* there was found a seedling (Co. 205) which possessed most of the desired economic characters of the two parents. It was at once multiplied vegetatively and distributed for cultivation. Similarly from the 'Noble' cane variety, striped Mauritius, there arose a red sport (Gillman sport) through gene mutation, which exhibited certain superior economic characters over the parent from which it sprang. It was clonally propagated and distributed for cultivation.

b. *Highly heterozygous polyploid: Variations in selfed progeny.* A marked feature in sugarcane breeding is that even in selfed progeny there is a very wide

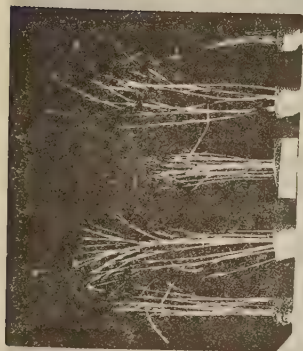
range of variation. The reason for this is that sugarcanes are polyploid hybrids, that is, two or perhaps more fundamental forms have entered into hybridization in nature accompanied by chromosome duplication. The various crosses and back crosses that took place during their evolution have made them highly heterozygous for several pairs of genes, that is, several different genes or their associations have entered into their formation. If we consider the behaviour of even simple hybrids which are heterozygous for one or two pairs of genes, then we can realize the complicated behaviour of a form like sugarcane, which is not only heterozygous for several gene pairs, but is also a high polyploid having several sets of such heterozygous chromosomes. If we cross a true breeding tall plant (TT) with a true breeding short plant (tt) we get a hybrid (Tt) which is heterozygous for one pair of genes, the gene T (gene for tallness) contributed by the homozygous tall parent, and the gene t (gene for shortness) contributed by the homozygous short parent. This hybrid Tt would look like that parent whose gene is dominant, say T, or would be intermediate in case there is no dominance. When the hybrid Tt forms sexual cells or gametes, T and t are separated during reduction division and if these two kinds of gametes come into contact at random during self fertilization, four kinds of individuals are formed, (TT), (Tt), (tT) and (tt). Of these the first three will be tall and the fourth will be short, in case of complete dominance. If the hybrid was heterozygous for two pairs of genes, that is, arose from parents differing from one another in respect of two pairs of characters, namely, stature and nature of seed, (TT SS, tall plant with smooth seeds, and tt ss, short plant with wrinkled seeds) the sexual cells formed by such a hybrid will fall into four classes, (TS), (Ts), (tS) and (ts). A random union of these four kinds of gametes in self fertilization would give rise to four kinds of visibly different individuals in the F_2 or second filial generation made up of parental forms TT SS and tt ss as well as those exhibiting now combinations of parental characters, like tall wrinkled (TT ss) and short plants with smooth seeds (tt SS). If a hybrid is heterozygous for several pairs of genes instead of only two, the number of kinds of sexual cells or gametes formed will be proportionately high, namely, 2 to the power of n ($2n^2$), where n represents the number of gene pairs involved and consequently the progeny of the hybrid will fall into as many different visible kinds and hence the wide range of variation. So in sugarcane, which is not only heterozygous to a high degree, but is also a high polyploid, the selfed progeny shows a very wide range of variation. The photograph (Plate VIII, fig. 4 A) shows the selfed progeny of *S. spontaneum* exhibiting variations among themselves. Among the 'Noble' canes, however, only a few forms are self fertile. Even in such forms there is not only variation in selfed progeny but also there is a very large percentage of mortality, only a few seedlings surviving. This is due to the presence of many lethal genes. These are recessive and are kept under suppression by dominant genes. So long as the plant is vegetatively propagated the lethal effect is not manifested. But during sexual reproduction the dominant and recessive genes are separated at meiosis, and among the various recombinations that take place during fertilization, such of the progeny in which the recessive genes, come together without having the protection of the dominant genes, die early. Since the percentage of mortality is very high, it is probable that there is a large accumulation of these recessive lethal genes.

c. Variations in hybrid population and impossibility of repeating combinations.

If we cross the sugarcane with another form which is also highly heterozygous, the offspring that result will be a heterogeneous population, no two of which can be alike. The parental characters are found distributed amongst the progeny. If they were merely hybrids from two true breeding parents, all of them should be alike, either resembling one parent completely or the other, according to which of the parental genes are dominant, or they should be intermediate. But here, there is a medley of F_1 population in some of which the earliness of one parent may show itself out and in others the thickness of the other parent may manifest itself. Yet in a few the high sucrose of one of the parents may be incorporated and it may also happen that in a few a combination of some of the desirable characters of the two parents may be found to occur. If in such a heterogeneous population we are able to get a form answering our needs it is obvious that it is impossible to resynthesise such a form by repeating the cross. To this extent the getting of a desirable seedling in the first hybrid generation has necessarily to be a hit or miss method. That is why in our breeding operation many thousands of seedlings are raised by controlled crosses between parents possessing characters whose combination to the largest possible measure is the main objective. The expectation is, the larger the population the greater the chances of securing such an individual. The photographs in Plate VIII, fig. 4B and 4C give an idea of the variations in the progeny of interspecific and intergeneric crosses respectively.

These variations are by themselves of great use to the sugarcane breeder, especially, because the maintenance of the desirable type got out of a matting of highly heterozygous parents is possible through clonal propagation. Otherwise it would not be possible to recover a pure breeding form through sexual means, because the new variety also will be heterozygous since the parents differed by many genes. The offspring which it would produce from seed would show great variation. Only a few of these would be sufficiently like the parents. These plants too would fail to breed true for they also would be heterozygous for a number of genes. After many generations it may be possible to establish a true breeding strain. The time, labour and cost involved are so great as to make this venture not worth while.

d. Fertility of and absence of segregation in sugarcane hybrids. The fact of all the known sugarcane, wild and cultivated being highly heterozygous polyploids reveals in a peculiar manner in species and even generic hybrids. Firstly, there is practically no segregation of parental characters, due to absence of pairing between parental chromosomes. In the hypothetical cross mentioned previously, we have assumed that the chromosomes containing gene pairs Tt and Ss were perfectly homologous and that they pair normally. Segregation was also normal in the sense that the parental forms could be recovered as also recombination of parental characters obtained. But if the two parents were widely different from one another, but near enough for the chromosomes of the two parents to exist side by side in the hybrid, the parental chromosomes would not pair. For instance in a cross between the radish and the cabbage, the hybrid had 18 chromosomes, being the sum of the gametic number of the two parents, namely, 9 from the egg of the radish and 9 from the sperm of cabbage. This intergeneric hybrid set no seeds though flowers were

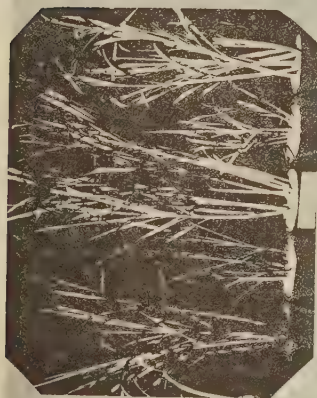


A

S. Spontaneum (Local)

Selfed progeny

- 1 Tall plant, Thin yellow green stem, narrow leaves.
- 2 Tall plant, Thick green stem, wide leaves.
- 3 Medium sized plant, Thin yellow green stem, Narrow leaves.
- 4 Tall plant, Thick purple stem, wide leaves.
- 5 Dwarf plant, very thin yellow green stem, Narrow leaves.



B

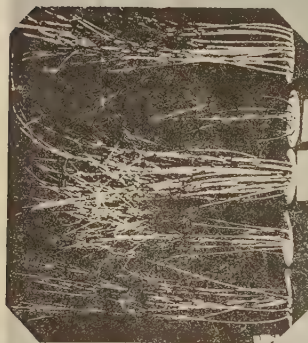
Inter-specific cross

S. officinarum var: Chittan

x

S. Barberi var: Saretha

- 1 Tall plant, Medium thick purple stem.
- 2 Dwarf plant, Thin greenish yellow stem.
- 3 Tall vigorous plant, Thick greenish yellow stem
- 4 Dwarf plant, Medium thick stem.
- 5 Tall plant, very thick greenish yellow stem.



Inter-generic cross

S. Spontaneum Local

x

Sclerostachya fusca

- 1 Tall plant, erect, medium thick, greenish yellow stem.
- 2 Medium plant, erect, Medium thin yellowish green stem.
- 3 Tall vigorous plant, Thick purple stem
- 4 Short plant, Thin yellowish green stem. Spreading habit.
- 5 Tall plant, Thick yellowish green stem. leaves wide.

Fig. 4

VARIATIONS IN THE PROGENY OF SACCHARUM AND ITS HYBRIDS

formed. It was sterile. It was found that pairing and exchange of partners that should normally take place between the maternal and the corresponding paternal chromosomes during the formation of the germ cells, egg or sperm, did not happen. This was because, the chromosomes of the two parents did not possess anything in common between them. Hence they remained unpaired as univalents instead of forming bivalents. It may be mentioned in passing that even in closely related species crosses, changes in the genic structure of one or more chromosomes may reduce pairing. The sexual cells that are formed from such partially pairing or non-pairing individuals receive unbalanced assortments of chromosomes in varying numbers and sterility results. But the sterility of a hybrid like that of radish and cabbage hybrid, need not be final. In a few of the sexual cells, eggs and sperms, the nuclei fail to separate during the first division. No partition wall is formed and a single nucleus with all the 18 chromosomes, 9 from cabbage and 9 from radish is formed. The 2nd division which is mitotic, separates this single nucleus into two daughter nuclei each having 18 chromosomes. In this way are formed a few eggs and sperms having the diploid number of chromosomes, instead of the haploid number as normal germ cells should, had they resulted from regular reduction division. If a diploid sperm fertilises a diploid egg, the plant that develops from it is a tetraploid having 36 chromosomes in which four sets of chromosomes are present, two sets from radish and two sets from cabbage. Such an allo-tetraploid derived from hybridization and chromosome duplication is fertile and true breeding. The cytological basis for this is that since two sets of radish chromosomes are present they pair among themselves (autosomesynesis) to form 9 bivalents. Similarly the cabbage chromosomes. The difficulty of non-homology between radish and cabbage chromosomes has been thus overcome.

The sugarcane has also had a similar origin through more complex hybridization, backcrossing, etc., accompanied by chromosome duplication. It is thus an allo-polyploid having several sets of the basic 10 chromosomes. If it were merely an allo-tetraploid having been formed by hybridization between two related species or genera accompanied by chromosome duplication, it must also breed true. But the large variation that we find even in selfed progeny show that it is highly heterozygous, derived from the union of germ cells dissimilar in respect of the quantity, quality and arrangement of their genes. Many of these are lethal in *S. officinarum* leading to high mortality of their seedlings. The genetical consequence of this internal pairability of chromosomes is that in most cases the sugarcane hybrids are fertile. Apart from species hybrids as between *S. officinarum* and *S. spontaneum* which are fertile, even intergeneric hybrids show fertility or partial fertility in several cases. For example, *S. spontaneum* with *Sclerostachya* gave fertile hybrids, which showed variations among themselves. Again the Sorghum cross with sugarcane which was made to introduce a shorter life cycle characteristic of Sorghum, showed among the hybrid progeny several forms which were fertile. They also showed variations in which parental characters were found distributed. The fertility of this cross, for instance, is due to the pairing among themselves of the 40 sugarcane chromosomes and the 20 Sorghum chromosomes, forming 30 bivalents. The variations exhibited by the selfed progeny of such hybrids are not very pronounced and such variations

as we find in this F_2 generation are due to exchanges of genes that have taken place among the sugarcane chromosomes on the one hand and among the Sorghum chromosomes on the other, and not between them. In other words in the formation of this F_2 population, no segregation of parental characters was involved according to Mendelian heredity. Consequently, neither the parental forms, that is, pure sugarcane or Sorghum, nor a recombination of distinct parental characters are recoverable.

e. Functioning of diploid gametes : Reciprocal crosses not identical : unpredictability of chromosome numbers in sugarcane hybrids. Another peculiarity which is almost unique in sugarcane hybridization is that no prediction can be made as to what the chromosome number in a particular cross would be like. Normally when two plants are crossed, the gametes, each with its haploid number of chromosomes enter into fertilization and the diploid chromosome number of the hybrid, irrespective of whether it is fertile or sterile, should be the sum of these gametic numbers. For instance, if *S. officinarum* ($n=40$) is crossed with *S. spontaneum* ($n=32$) one should expect the hybrid to show a diploid number of $2n=72$. But we find the hybrid showing $2n=112$. It means that the female parent *S. officinarum* has contributed the diploid number of chromosomes through its egg, which normally should contain only the haploid number of chromosomes, having been derived from a reduction division of the mother cell. On this basis, the resemblance of the hybrid progeny to the female parent is understandable, in that the number of maternal chromosomes far exceed that of the paternal chromosomes. How about the reciprocal cross? In any cross, say, between a tall and a dwarf plant, it should not matter whether it is the tall plant that is used as the female parent, or *vice versa*. But in some *Saccharum* hybrids we find a difference in the hybrid progeny in reciprocal crosses. For instance in a cross between *S. officinarum* \times *S. spontaneum* (the first parent is the female) the progeny though differing from one another, resemble more the *S. officinarum* parent for which there is cytological justification, as has been indicated above (Plate IX, fig. 5 A). But in the reciprocal cross, having *S. spontaneum* as the mother the progeny resembles more the *S. spontaneum* parent even though it is the *officinarum* that has contributed the diploid number through its sperm (Plate IX, fig. 5B).

This is not all. Some crosses show a number which is neither the sum of the haploid numbers of the parents, nor the sum of the diploid number of one and the haploid number of another. For instance, Co. 453 is a cross between *S. officinarum* variety Black cheribon ($n=40$) and Co. 285 ($n=56$). It should show either $40+56=96$ or $80+56=136$. But it actually has 124. It means that the female parent has contributed, through its egg, a number which is neither its haploid number (59) nor its unreduced number (80), but some unexpected number (65). What the significance of this non-reduction and partial reduction in the formation of the egg is likely to be is not yet known. It also appears likely as disclosed by the *S. spontaneum* \times *S. officinarum* crosses that this non-reduction need not be confined to the egg, but that the sperm may also contribute the diploid number. How far this phenomenon is common in all the species of *Saccharum* and to what extent, and if it occurs in related genera also, remains yet to be investigated.

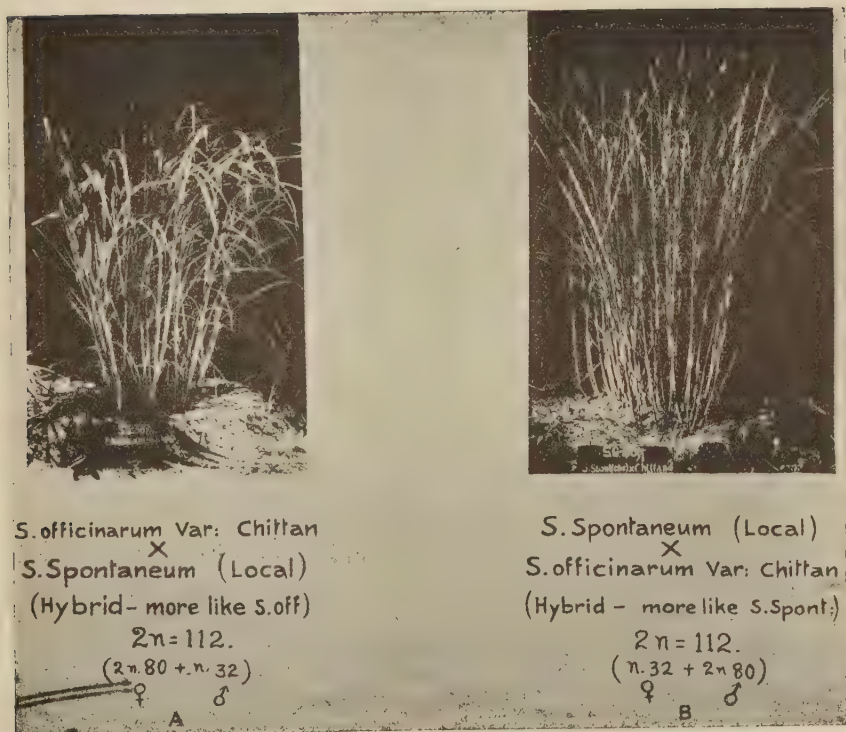


FIG. 5
NON-IDENTITY OF RECIPROCAL CROSS

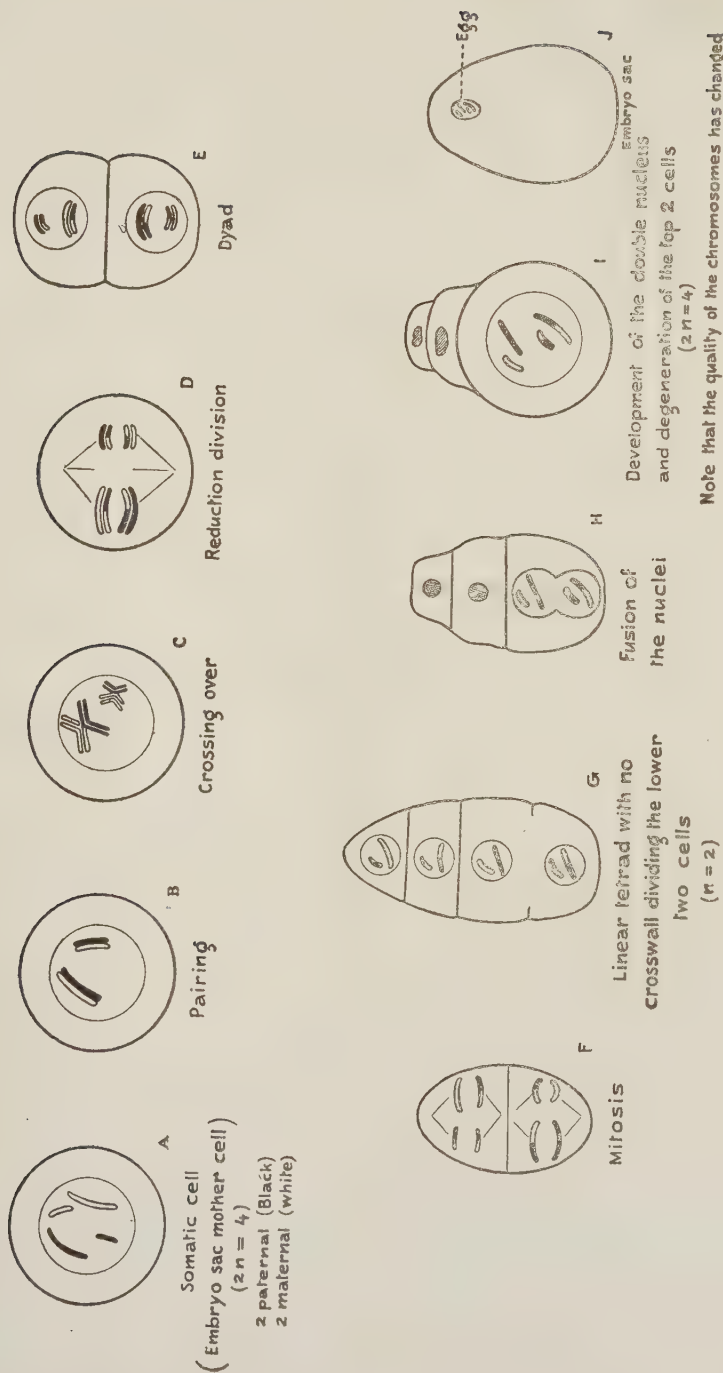


Fig. 6. Formation of diploid egg.



- | | | |
|---|---------------------|------------|
| 1 | Co. 421 | $2n = 118$ |
| 2 | Thick (Like mother) | $2n = 118$ |
| 3 | Thin | $2n = 86$ |

FIG. 7

PARTHENOGENETIC DERIVATIVES FROM Co. 421

f. Mechanism of non-reduction in egg parthenogenesis. But the mechanism of this non-reduction of the egg in *S. officinarum* is known. It is also unique. Functioning of diploid eggs in other plants is by no means uncommon. But usually such diploid eggs are formed through suppression of the mitotic division. The diploid chromosomes in the mother cell may not pair at all. No meiosis takes place and the egg comes to possess the somatic number of chromosomes. It is just like any other somatic cell and if by any chance such a diploid egg were to grow into a daughter plant straight away without being fertilized by a sperm, the latter will be just like the mother plant in all respects, because the daughter is actually an outgrowth, from a somatic cell derived by a repeated mitotic division of it. It is for all practical purposes clonally reproduced. Since it is not derived from a vegetative bud as usually clones are, but from an unfertilized egg cell, it is a case of parthenogenesis. The essential feature of such a parthenogenetic derivative is that it is just like the mother, having been asexually formed by repeated mitotic divisions of an unfertilized egg, which for all practical purposes is a somatic cell.

In sugarcane, however, such is not the case. Even parthenogenetic derivatives show variation among themselves. This is traceable to the mechanism by which the diploid egg comes to be organized. Here it is not due to suppression of meiotic division. But reduction division does take place as usual (Plate X, fig. 6, A to F), which means that the homologous chromosomes have paired, exchanged partners and separated, bringing with it a reshuffling of the parental genes. After reduction division four haploid germ cells are formed, two of which fuse to form a single diploid cell (Plate X, fig. 6, G and H) from which the diploid egg is organised (Plate X, fig. 6, I and J). Since such an egg has come into being after reduction division, reshuffling of characters has already taken place during its formation. No two eggs of such origin can be expected to be identical, in respect of the assortment of the parental genes. The consequence is that the plants derived from such eggs, even though without fertilization, show a wide range of variation, in respect of vigour, fertility and even sucrose contents. Several Co. canes like 461, 462, 463, 656, 779 derived from Co. 421 as the mother and different father show only the maternal number of chromosomes obviously they are all a result of parthenogenesis. But they differ from one another in every way. Coupled to this, where the forms so derived have the same chromosome number as the mother, is the phenomenon in which only some of the chromosomes after meiosis, take part in the production of the daughter plant, by parthenogenesis. For instance Co. 421 which is a pollen sterile form, when selfed gives rise to progeny which must obviously have arisen parthenogenetically, because no fertilization could have taken place. Some forms are like the mother and contain the same chromosome number ($2n=118$). So these are derived from the unfertilized egg cell of the mother, in which the diploid number of chromosomes had come into being, in the manner described above. The others are much thinner. They contain a diploid chromosome number of 86. These have been formed from unfertilised egg in which there were only 86 chromosomes, the remaining not taking part in egg formation. Photographs in Plate XI, fig. 7 show the mother and the two

parthenogenetic derivatives. This only makes the range of variation among the parthenogenetic derivatives more marked. It may so happen that among these are found a few with desirable characters, which of course can at once be fixed by vegetative propagation such have the Co. canes mentioned above been derived.

The work of sugarcane breeder is thus interesting in the extreme as he is faced with an element of uncertainty and surprise at every stage. But his problem is to bring it within the operation of Mendelian laws of heredity. One possible way of achieving this is to break down the polyploidy of the species and if this were done, we can make the chromosomes behave in the same way as a normal diploid plant in respect of hybridization. Incidentally we can know something about the origin of the cultivated forms and if this is known it is possible to apply the method for the creation of the desired varieties. From this point of view, the work of the sugarcane breeder is almost the reverse of the breeder of most other plants. The latter usually builds up new forms by chromosome duplication induced artificially by crossing and by treatment with alkaloids like colchicine. But the breeder of sugarcane has to work his way in the other direction by breaking down the polyploidy and reducing the chromosomes to their basic number. In devising suitable methods for this purpose, the several interesting, though unpredictable and in some cases unexplainable crossing results will be of the utmost help, by showing him the possible way by which to proceed among the maze of seeming contradictions, in which sugarcane cyto-genetics abounds.

REVIEWS

FERTILITY FARMING

By NEWMAN TURNER

(Published by Faber and Faber Ltd., 24, Russell Square, London, 1951 ; Price 16s)

IN more than one agricultural circle recently the subject of mineral vs. organic fertilisers has been felt to be a suitable topic for a symposium. Such a symposium was held as late as January 1951 during the Science Congress in Bangalore, and among other scientific workers in this country the reviewer made his own contribution.

The interest of the subject derives from the fact that it really represents the fundamental points of view which may be broadly termed chemical and biological. The chemical or NPK school owes its origin to Liebig. The modern school concerned more with what may be described especially as fertility problems rather than agriculture, may be termed *biological*, and its main inspiration is to be found in the writings of the late Sir Albert Howard. In this connection Nitrogen is not thought of so much as the simple element but rather as protein or nitrogenous food. A *fertile* soil is thought of as one rich in *humus* which may be usefully considered as vegetable protein. The problems of 'Fertility Farming', then, centre round the maintenance of a soil of adequate humus content. The most practical method of adding organic matter rather than mineral elements is based on the methods employed by the farmers of China for 40 centuries, viz. the production and utilisation of *compost*, i.e. the fermenting together of the available cellulosic with the nitrogenous waste material of the farm and returning the product to the surface of the soil where it may be reoxidised and thus find its place once more into the cycle of nature.

This is the briefest outline of the Howard school of thought, but the book under review is primarily concerned with the practice rather than the philosophy of that school. As the publishers say, 'this new system is given costings and tables from a working farmer with courage to prove that it *pays* him to farm for healthy soil and healthy stock'.

The criticism thus is often made that composting is heavy in labour cost, and such criticism has certainly adversely influenced the ready utilisation of urban organic matter for agriculture in England. Only practical experience, reinforced by actual figures of cost, can successfully refute such criticism, and the especial importance of the book derives exactly from such facts and figures based on actual experience. As regards the alleged cost of composting, the author says that one can reckon that the cost of artificials on most farms would more than pay for a

man for a whole year making compost. He says: 'Certainly on my farm our expenditure on fertilisers under orthodox methods was equal to far more than the wages of *two men*'. The reviewer's own personal experience confirms this observation.

Even from the purely monetary point of view, 'Fertility farming', as practised by the author, is a very paying proposition. This is what he says in regard to his own experience: 'The farm was purchased in 1941, when I started as manager, for £7,500. I gave £10,400 for it in 1946. It was valued in 1950 at £19,500. I am told that certain further improvements, since that valuation, make it now worth £25,000. This means, in any case, that since I started, its value has increased by over £17,000. Some of this is due to general increase in land values, but I am assured by those who know, that the actual value of the farm, quite apart from market changes, is at least double what it was when I took it over as a 'C' farm ten years ago. And that to me is the true farm profit, for it is the only accurate way of measuring a farmer's success.

This reviewer unreservedly agrees with the author's view-point that the modern compost heap is as important as any agricultural discovery of recent years.

The compost heaps thus becomes the centre of the modern farm. It is indeed happening in many parts of the world, e.g. in New-Zealand and South Africa. Where the real operations of nature are scientifically understood, the financial and economic results, which the author has demonstrated, must of necessity follow. After all there are no secret processes mentioned in the book. The book indeed constitutes a text-book since the author sets out a definite programme of agenda of 52 weeks of Fertility farming.

Other very important aspects of his practice include the avoidance of the use of the plough, the complete elimination of all chemical 'aids' to farming and livestock management, and the extensive use of herbs in the dietary of the cattle in the treatment of disease.

This reviewer has spent his scientific life in the field of sewage purification, and particularly its utilisation for the benefit of agriculture. Indeed the main objective of the activated sludge process of sewage purification, which he pioneered, was to help, make two blades of grass grow where one grew before, and it is therefore especially pleasing to the reviewer to read the author's remarks: (P. 249). 'There is one further provision which is essential to complete the cycle of fertility and it is an urgent and imperative one if Britain is to evade eventual starvation. That is the return to the soil—properly composted, to avoid unpleasantness—of all sewage sludge and organic town refuse.'

Whole sections of mankind are facing imminent starvation, and until the lesson is learnt that the cycle of nature should be scientifically completed, the danger will not pass. How in *practice* to complete nature's cycle is the theme of the book under review, and no responsible agriculturist or public man can afford to ignore such knowledge. (G. J. F.)

MECHANISATION OF AGRICULTURE IN INDIA : ITS ECONOMICS

By JYOTIPRASAD BHATTACHARJEE

(Published by Viswa Bharati, Sriniketan, Birbhum, pp. 58, Price Rs. 1-8 as.)

THIS is a book which should carefully be read by those who think that the mechanisation of agriculture in India, is the only means of removing the country's poverty. The author has explained clearly the disadvantages and difficulties of mechanising the agriculture of our country under the present economic background. He has explained at length the conditions of and pre-requisites to mechanisation of agriculture in India on technological as well as economic grounds. Truly the technical conditions of land holdings in India are at present unsuited to mechanisation. Before mechanisation can be taken up, the holdings should be consolidated by co-operative or other methods. The author rightly doubts if the mechanisation can increase the output and says 'even if it does, the increase in yield is to be attributed to the implements and accessories attached to the power machines. While therefore, there is every reason for introduction of improved implements in India, the case for adoption mechanical power is not so strong or convincing'. He then points out the technological limitations and the economic condition which are not favourable to mechanisation and the technical education which is so essential for the purpose is also lacking. Mr. Bhattacharjee has discussed frankly the advantages of mechanisation so also the bad effects of it. Among the bad effects he mentions ' (1) displacement of labour from land and the consequent fear of unemployment which is very real in a country like India (2) tendency towards capitalistic farming in as much as mechanisation strikes at the root of peasant or subsistence farming (3) the consequent growth of a landless proletariat class (4) slump in agricultural prices nullifying all advantages of mechanisation and (5) a revolutionary impact on the existing economic and social structure leading to much distress and upheaval'. No doubt Mr. Bhattacharjee's arguments are based on certain amount of logic but to my mind he has expressed his apprehensions rather too much. The sponsors of agricultural mechanisation will of course have to consider the questions put forward by the author of this book, and also they will have to look for the alternate employment of labours released from the agriculture after mechanisation to avoid the breakdown of economic and social structure. This probably will not be so difficult if industrialisation of country proceeds simultaneously with the mechanisation of agriculture in the country.

The author has concluded saying that under the present conditions of the country, the mechanisation should be carefully planned at slow pace. The agrarian reforms should be directed towards the establishment of state farms on state lands, collective farms on lands of poor quality and the cultivable wastes, cooperative farms on less densely populated areas and individual farms of an economic size in other areas. The policy of mechanisation of agriculture should be forerunning policy of imparting mechanical sense and technical training among the farmers. Although the need for the technical training has already been felt and a beginning

to remedy the need has been made by the Government, steps should be taken to implement all these suggestions of the author, which are really considered to be essential, by those responsible directly for the mechanisation plan.

The book, as it is, presents a very pleasant reading and contains many thought provoking materials. The language is lucid and difficult economic propositions have been explained in an interesting manner and style. The book deserves wide-spread publicity. (T. S. M.)

THE JUTE SPINNING PADDLE WHEEL

By SATISH CHANDRA DAS GUPTA

(Published by *Khadi Pratisthan, Calcutta and Dacca*, 16 + IV pages D/C.
Price, 8 annas)

SRI DAS GUPTA, a well known champion of cottage industries, described in details and with nine diagrams, the construction and mode of working of his spinning wheel in this little pamphlet. For 'batching emulsion' is used plain water, and for the 'softener' hand beating. Root is not apparently rejected for any kind of yarn; no 'binning' is done, as in industrial practice. Consequently, preparation of the fibre for the wheel becomes a lengthy, laborious process. This might possibly be shortened, to a considerable extent, by a simplified softening process, with oil-in-water emulsion and binning in small wooden boxes. The functions of the Breaker Card, Finisher Card, First and Second Drawing, as well as Roving machines have been omitted. It is not mentioned how the meshy structure of jute is split up before spinning; some sort of combing is necessary for this. The count and regularity of the yarn depend upon such operation. The spinning wheel is a simple machine that may be operated by an ordinary worker but as is natural, quality and speed of production will largely depend upon the skill one attains.

The output figures (presumably for an average worker) are however, extremely low—one operator can produce with the help of this spinning wheel only about 2½ lb. of yarn (12 to 30 lb. grist) in 12 hours i.e. 1½ working days. For this he is to get only 12 annas i.e., 8 annas a day, ignoring the question of wastage, capital expenditure, and the like. Obviously, under the present circumstances, this hardly presents a practical proposition. But for those people in the country-side who have no occupation for some months of the year, this may provide a means of earning a little. Like the *charka*, it may as well prove a source of income in spare hours. Binding twines (for which no high grade yarn is required) which have a ready home market, may be tried in this spinning wheel rather than yarn for making of gunny bags. Cheap basic dyes may be used to make these attractive. The requisite quantity of wood for making such a spinning wheel is mentioned at the end but no approximate cost. As the author says, it is hardly suitable for making moderately fine used in hessian. (P. B. S.)

ECONOMIC SURVEY OF ASIA AND THE FAR EAST, 1949*

(Published by the Economic Affairs Department of the United Nations ; pp. 485, Rs. 15)

THIS survey of over 500 pages gives a full analysis of the economic situation in Asia and the Far East during the year 1949. The various factors and problems underlying post-war economic development in this Region are examined in detail and the conclusion is reached, that, although the year 1949 may have been a turning point in the economic recovery of the Region, it would be totally unrealistic to anticipate any rapid increase in the standard of living and welfare of the peoples therein, in the near future. On the other hand, it is emphasized that, for the next five years, at any rate, it would take all the available resources of the Region to maintain the present levels of production and consumption.

This sober conclusion may not be liked by many, but dispassionate observers must agree that the conclusion is based on an able marshalling of facts and figures. Fully documented with statistical data and charts, this survey supplies a long felt demand for up-to-date and accurate information on economic conditions in this Region. (N. D.)

* Available in India from the Oxford Book and Stationery Co., Scindia House, New Delhi.

ADAPTATION AND ORIGIN IN THE PLANT WORLD

By FREDERIC E. CLEMENTS, EMMETT V. MARTIN and FRANCES L. LONG

(Published by The Chronica Botanica Company, Book Department, Waltham, Mass ; U. S. A. ; 1950 ; pp. 352 with a glossary)

THE book records the final results of experiments planned to study the influence of environment on plants. The controlled experiments have been carefully designed the object of which are stated below :

‘The primary objective of the studies in adaptation is the production of new forms under measured control and the relation of these to the ecads resulting from natural experiments. This involves a minute analysis of the process and especially of the extent to which it acts as a selective agent. Consequently it demands not only the detailed correlation of factor and function, but likewise an inquiry into the energy relations concerned in the latter. With respect to evolution, the crux of the problem lies in the reciprocal action of adaptation and fixation and in a comprehensive analysis of heritable and non-heritable changes.

For details the reader must refer to the pages of the book.

Records indicate that the effect of changed habitat may even lead to speciation. It is an accepted view that manifestation of characters in an organism is the result of the interaction of heredity and environment. Alteration of one or the other will alter the final result. The question is whether the effect of environment will go so far as to lead to speciation.

The definition of species is generally based on external morphology of the specimens. The experimental results recorded in the book under review make it abundantly clear that environmental influence produce characters indistinguishable from specific characters and the individuals thus modified would be regarded as distinct species if found in nature.

The get up of the book is excellent. Illustrations are appropriate and clear. The glossary at the end is a valuable addition.

The book will be useful to students of taxonomy, ecology, agriculture and horticulture. (P. P.)

VEGETABLE CROPS

EDITED BY H. C. THOMPSON (Cornell University, U.S.A.)

(Published by Mc-Graw-Hill Book Company, Inc. 330 West 42nd Street, New York 13, U. S. A., fourth edition, pp. 611)

SINCE 1940 when the 3rd edition appeared there has been great advance in research on vegetables both in regard to breeding and production. It was appropriate that a revised version should have been published including results of investigations carried out during the last 10 years. The book, as now presented, furnishes valuable information on general aspects such as requirements of climate and soil for growing vegetables, their food value, etc. Allied vegetables are grouped together and requirements of each crop are treated in a specialized manner under statistics, history, soil preference, manure, sowing, after-care and protection from pests and diseases.

The book is divided into 27 chapters of which the first fifteen deal in a logical sequence under separate heads with important topics such as classification, manures, fertilizers, planting, cultural operations, marketing and storage. Chapters 16-27 comprise vegetables grouped under their distinctive characters such as perennial crops, i.e., asparagus, rhubarb, etc.; greens such as spinach, mustard, collards; salad crops such as celery, lettuce, etc.; cole crops such as cabbage, cauliflower, kohlrabi, etc.; root crops and bulb crops. The potato and the sweet potato are rightly given special chapters on account of their great importance in human diet and extensive cultivation. Beans and peas are appropriately dealt with together. Tomato, egg plants, cucumber, musk melon, sweet corn, etc., are given under the category of fruits and find a place under vegetables. There can be no strict demarcation as to their uses for either purposes. Reference to diseases and insect pests and their control measures will be very helpful to vegetable growers, both amateur and commercial. The hints are given very clearly and in a very practicable form.

The literature cited at the end can be referred to for any detailed and special study of particular aspects of the subject. The book can be recommended as a very instructive guide for culture of vegetables and as text-book in Agricultural Colleges. (J. C. L.)

FLORICULTURE : FUNDAMENTALS AND PRACTICES

BY ALEX. LAURIE AND VICTOR H. RIES

(Published by McGRAW HILL, New York and London, New Edition,
pp. 525 ; Price 5 Dollars)

THIS book has been prepared primarily as a text for the teaching of a course dealing with ornamental gardening. As such, the authors have attempted to put together in a brief but accurate form the basic information underlying the many empirical practices and at the same time to provide materials that would serve the general coverage of a course intended for students in horticulture and also to aid those who wish to obtain information in compact form for cultural purposes.

The book is divided into 19 chapters. The first three deal with such fundamental aspects as how plants grow, soils and fertilisers, various growth-influencing factors, variety and characteristics of soils and manures with their functional importance. The next five chapters deal with horticultural taxonomy containing a brief synopsis of the more common characteristics used in identifications of plants with keys and suitable diagrams ; soilless culture and its technique, garden designing with detailed information on the layout and development of gardens for various purposes, and propagation of plants, lawns and their layout and the various annuals, perennials and other flowering plants with lists of suitable plants for horticultural purposes under each. Flowering bulbs, rock gardens, roses and water gardening are discussed in subsequent chapters, as also woody plants, house plants and green house management with exhaustive illustrative examples. There is a separate chapter on insect pests and diseases of garden plants. Bibliographies appended to most of the chapters offer a selection of references for follow up, and the index forms a valuable appendage to the volume.

Incorporating the recent techniques in Floriculture, this revised edition of the book will certainly be found useful to students of floriculture. (M. R. P.)

MANUAL OF LAW FOR FOREST OFFICERS

EDITED BY JAGDAMBA PRASAD

(Published by Oxford University Press, 1950, Price Rs. 5-8-0, pp. 151)

THE book is a welcome revision of the now out-of-date *Explanatory Notes on Forest Law*, which remained the only text book for forest officers for almost a quarter of a century. Though not comprehensive enough for a Research Scholar, this small volume, in its 19 chapters, contains all that a forest officer is expected to know about Law in his day-to-day administration. The general principles of Criminal Law, and the Law of Criminal Procedure will afford the necessary

background of knowledge to the young forest officer, who has to deal annually with hundreds of forest offences in some districts. The Law of Evidence, though not quite pertinent, will add a desirable mental equipment.

Government control over private forests is a subject of topical interest. Forestry is a long-term investment, and the owner has often to wait for over a century before the maximum return from his forests could be obtained. In every country it has been found that private owners are often unwilling to exercise long and uniform control over themselves. In India, too, there has been no exception. The private owners and *zamindars*, being afraid of talks of dispossession, and finding a seller's market in timber in post-war India, started ruthless destruction and over-exploitation of forests, to the detriment of the general rural economy. Chapter V of the Indian Forest Act was found to be unequal to the task of controlling such large-scale denudation. Accordingly special Acts have been passed in the Uttar Pradesh, Bihar, West Bengal, Orissa, Madras, and Madhya Pradesh to cry halt to the deteriorating situation; the scopes of these Laws are far-reaching and almost revolutionary. No mention of these Acts has been made in Chapter VIII. It is hoped that in the next edition of the book a detailed comparative study of these modern Laws affecting the rights of private owners will be made. In the meantime the general notions regarding rights and servitudes will help the private owner to appreciate the general limit that every man must so use his property as not to harm that of another. I, therefore commend this book to all private owners of forests, *zamindars*, forest officers and students all of whom will find stimulating thoughts and ideas in it. (M.D.C.)

READING IN RURAL PROBLEMS

By V. V. SAYANA

(Published by M/s. S. Chand & Co., Delhi, Price Rs. 5, pp. 184)

THE booklet has a rather ambitious and even misleading title and a reader is disappointed if he picks it up to find any *Readings* other than the articles, etc., contributed by Dr Sayana to various magazines and weeklies during the last two or three years. Many of these were of topical interest when written originally while a few could, for obvious reasons, find no place in any journal so far. Lacking in an abiding interest their reprint now even after a revision was hardly necessary much less under the title which the collection bears.

The subjects covered by Dr Sayana range from scope and method of teaching and research to inflation and forests a very wide range indeed for an individual to cover coherently in a single work. The contents, however, do not always lack good reading material and at places embody the results of first hand field investigation by the author in the State of Madras. These localised observations have wider implications and deserve a careful consideration.

It is delighting to find here a foreword, erudite and succinct by Prof. A. W. Ashby wherein he has drawn attention to the basic problems of our agricultural economy. 'The problem of Indian agriculture and of its contributions to national wealth and welfare are of technical, economic and social character. Relatively low productivity of both land and labour, in many parts of her agricultural system, is partly due to technical but partly also to economic conditions.' How evident and yet how little translated into policy making and measures is this inter-relationship of the factors in the equation.

The print and get up of the book leave much to be desired and do little credit to the publishers. (B. S.)

PROCEEDINGS OF THE UNITED NATIONS SCIENTIFIC CONFERENCE ON THE CONSERVATION AND UTILISATION OF RESOURCES

(Published by United Nations, Department of Economic Affairs, Lake Success, New York, 1952, \$4.50, pp. 431)

THIS is the first of a series of eight volumes which are being issued by the Department of Economic Affairs, United Nations, Lake Success, N. Y.

In September 1946, President Truman stated that the real or exaggerated fear of resource shortages and declining standards of living had in the past involved nations in warfare; hence conservation and adequate utilisation of the world's resources could become a major basis of world peace and prosperity. It was felt that a conference of experts representing all the participating countries in the U.N.O. would offer 'the most desirable method of presenting and considering many problems in the resource field', e.g., new techniques developed through scientific and industrial research, utilisation of resources of under-developed areas, special technical aid to such areas and to areas suffering from resource depletion, plans and patterns of resource use in the participating countries, etc.

Fifty two countries, twentytwo non-governmental organisations, and 152 learned societies participated in this conference. Eighteen plenary meetings were held where the discussions mostly dealt with summarized data, conclusions and fundamental principles. It was the consensus of opinion that through the less wasteful use of resources the fuller application of existing techniques and the exploitation of new scientific developments, it was possible to support a far greater population than exists to-day at a much higher level of living. This, however, demands an adjustment in the political, social and economic spheres, more or less, on a 'one world' basis, in order that full application of conservation and development technology may be assured. Conservation of non-renewable resources should be emphasised primarily where there are imminent shortages. Scientific knowledge and technical skill are in themselves the world's greatest resource. This resource is rapidly expanding and may soon make resources in material and energy, now considered essential, of secondary importance. Excessive preoccupation with conservation of resources should, therefore, be discouraged.

It was generally agreed that the development of tropical lands and forests depended largely on future scientific research, as the soil and forest science, as we know it to-day, was primarily applicable to temperate climates. Multi-purpose development of river basins was naturally considered as the most important method not only of conservation of soil, forest and water, but of harnessing the vast power irrigation and navigation resources of the world's great rivers.

Proper nutrition, specially of the population of the poorer countries, was discussed at length, and the possibilities of synthesising protein and fat as edible food through the aid of micro-organisms were envisaged.

Resource surveys and inventories are essential before the planned development of any region can be taken in hand; it was noted in this connection 'that growing improvements in the techniques of surveys and their interpretation were making them cheaper and more universal in application'.

Besides the plenary conferences, fiftyfive sectional meetings were held, and the proceedings of these meetings are intended to be published in the next seven volumes of this series.

This publication will no doubt prove very useful to resource technicians, Planning Authorities and Development Departments of Governments. (J.C.G.)

AGRICULTURAL SCIENCE ABSTRACTS

THE COMMONWEALTH AGRICULTURAL BUREAUX provide a comprehensive abstracting service in the agricultural sciences. A Staff of over 100 scientists translators and indexers produce some 30,000 abstracts annually, published in a series of journals which are obtainable by subscription. The subjects are :—

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